Water Power
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

1. Runner for No. 2 Turbine on the last stage of the journey to the Zambesi.

STAGES DURING CONSTRUCTION

2. Placing No. 3 Bottom Cover and Suction Cone.

3. A Runner prior to shipment.

4. A Runner being lowered into position in the underground power station.

ENGINEERING COLLEGE LIBRARY, TEXAS

Boving are supplying the six Water Turbines for Kariba, each of 140,000 h.p. Work is keeping pace with schedule and No. 3 turbine is approaching the completion stage

MAY 24 1960

Boving

AND CO LIMITED

WATER POWER ENGINEERS
VILLIERS HOUSE
41-47 STRAND - LONDON WC2

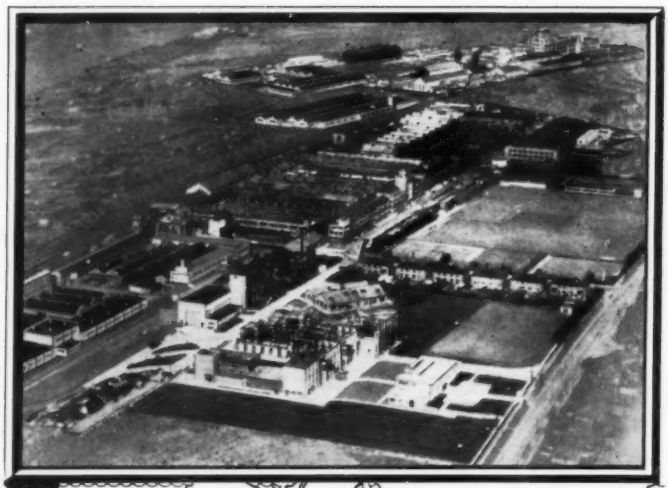
P.4476

HEBBURN–

THE SOURCE

OF ELECTRICAL

SWITCHGEAR



• ***ENGINEERS AND REPRESENTATIVES AVAILABLE FOR CONSULTATION AND ADVICE***

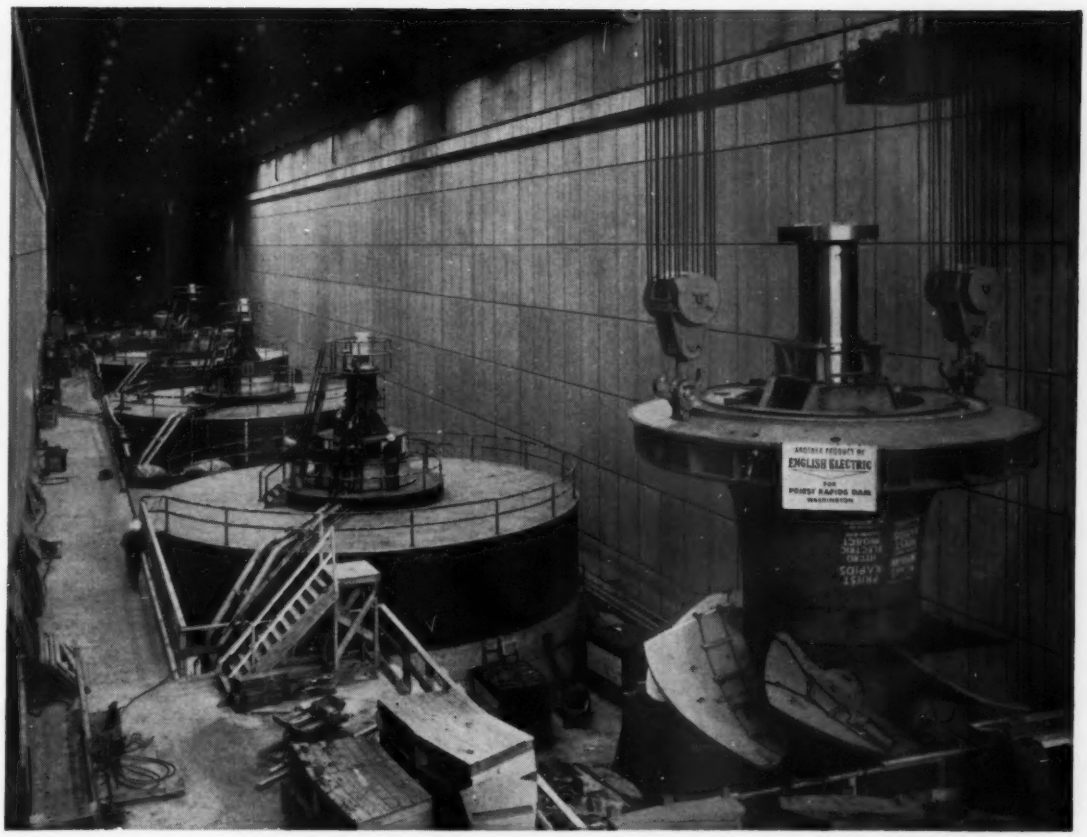
A WORLD-WIDE ORGANISATION

A WORLD-RENOWNED PRODUCT

REYROLLE

A MEMBER OF THE NUCLEAR POWER PLANT COMPANY LIMITED

A. REYROLLE & CO. LTD. HEBBURN COUNTY DURHAM ENGLAND



Ahead of schedule at Priest Rapids

Six of the ten 'ENGLISH ELECTRIC' 91,000 kW water turbine alternators are already on commercial load in the powerhouse at the base of the Priest Rapids Dam on the Columbia River, U.S.A. This recent view shows the progress of the installation of 'ENGLISH ELECTRIC' generating plant in support of a programme to have machines delivering full load power over one year ahead of schedule.

'ENGLISH ELECTRIC'

hydro-electric equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

Hydro-Electric Department, Dunnings Bridge Road, Netherton, Bootle, 10

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

HE.39

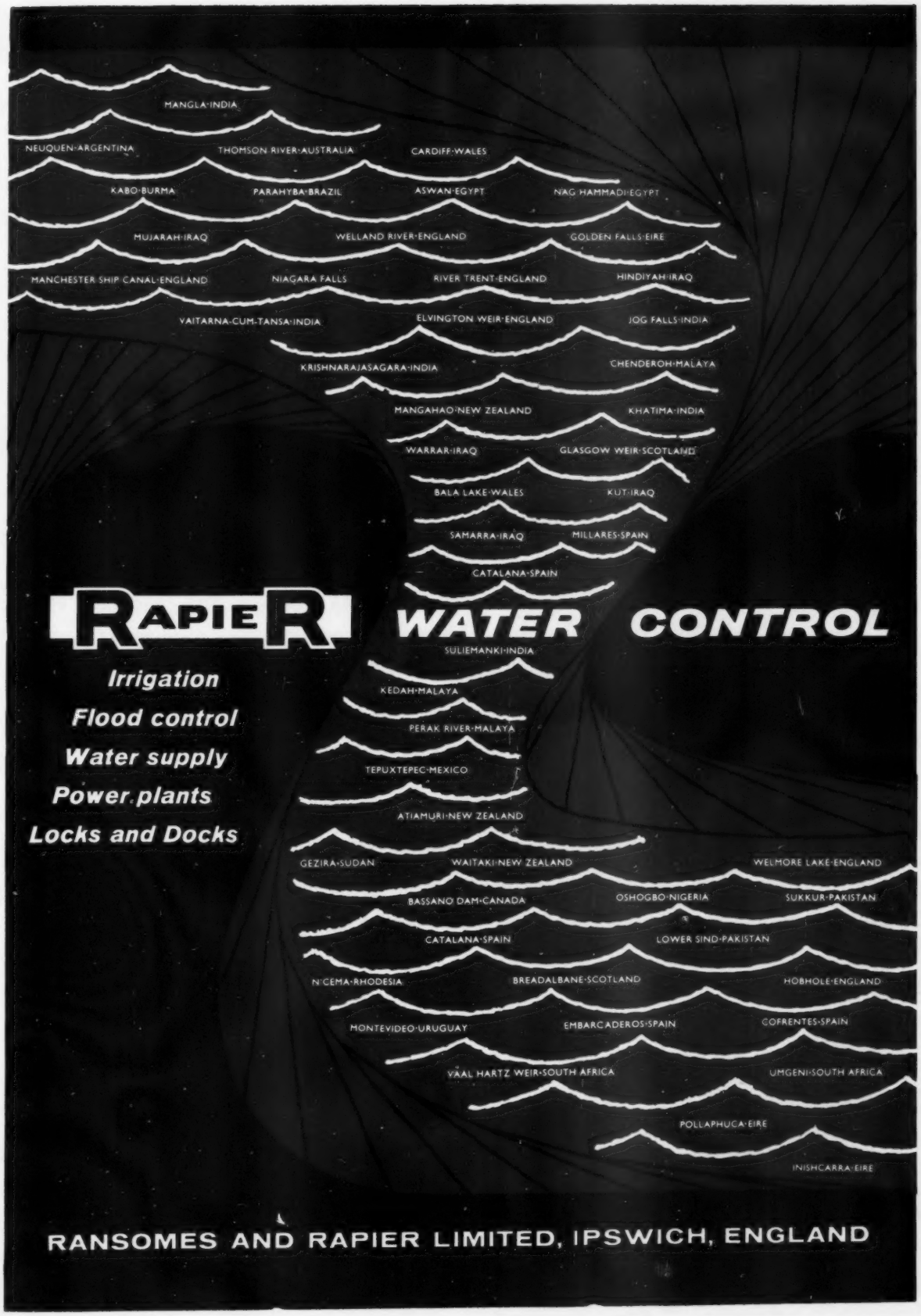
Toshiba

Contributing to better living for you!

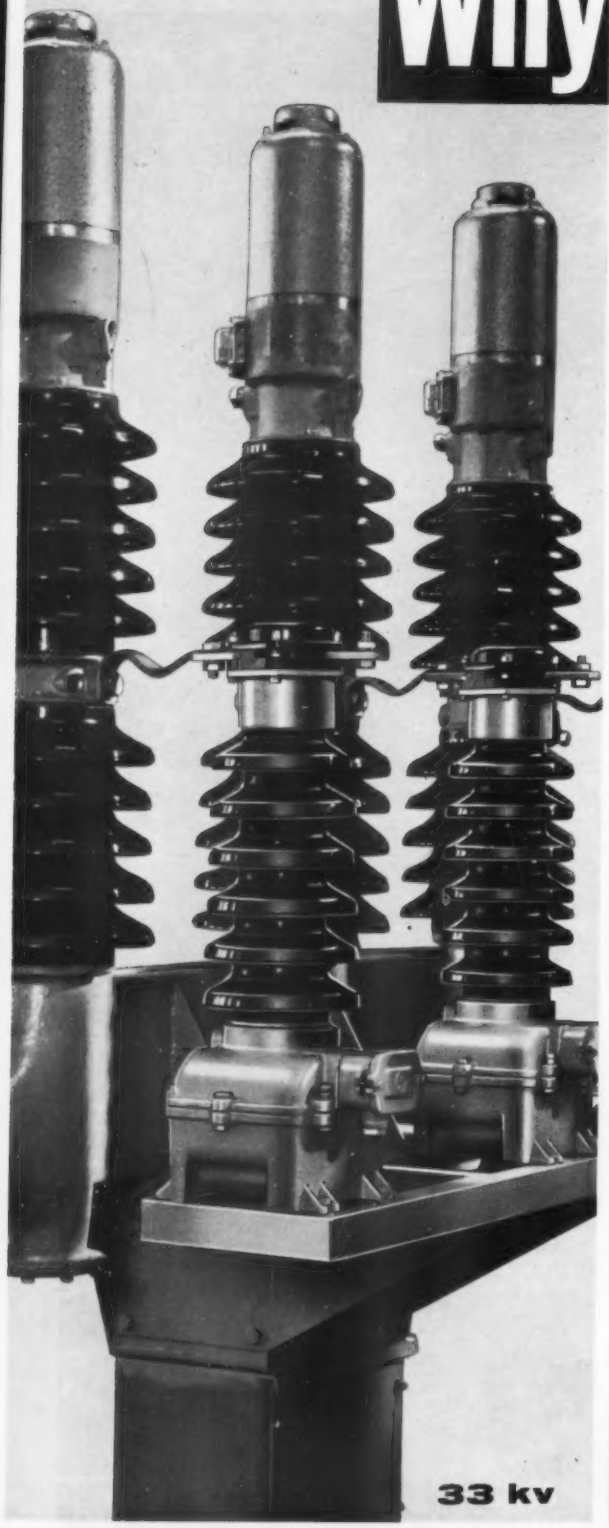
The giant 133,000 kVA water wheel generator pictured above is one of several produced by Toshiba for Japan's new Okutadami Power Project. It is of the umbrella type with vertical Francis turbine and is the biggest of its kind in the Orient and the second largest in the entire world. This is merely one of Toshiba's achievements in the field of hydroelectric equipment and is only one of the ways in which Toshiba is contributing to better living for you!

TOKYO SHIBAURA ELECTRIC CO., LTD.

2, Ginza Nishi 5-chome, Chuo-ku, Tokyo, Japan Cable Address: TOSHIBA TOKYO


MANGLA·INDIA
NEUQUEN·ARGENTINA
THOMSON RIVER·AUSTRALIA
CARDIFF·WALES
KABO·BURMA
PARAHYBA·BRAZIL
ASWAN·EGYPT
NAG HAMMADI·EGYPT
MUJARAH·IRAQ
WELLAND RIVER·ENGLAND
GOLDEN FALLS·EIRE
MANCHESTER SHIP CANAL·ENGLAND
NIAGARA FALLS
RIVER TRENT·ENGLAND
HINDIYAH·IRAQ
VAITARNA-CUM-TANSA·INDIA
ELVINGTON WEIR·ENGLAND
JOG FALLS·INDIA
KRISHNARAJASAGARA·INDIA
CHENDEROH·MALAYA
MANGAHAO·NEW ZEALAND
KHATIMA·INDIA
WARRAR·IRAQ
GLASGOW WEIR·SCOTLAND
BALA LAKE·WALES
KUT·IRAQ
SAMARRA·IRAQ
MILLARES·SPAIN
CATALANA·SPAIN
RAPIER
WATER CONTROL
Irrigation
Flood control
Water supply
Power plants
Locks and Docks
SULIEMANKI·INDIA
KEDAH·MALAYA
PERAK RIVER·MALAYA
TEPUXTEPEC·MEXICO
ATIAMURI·NEW ZEALAND
GEZIRA·SUDAN
WAITAKI·NEW ZEALAND
WELMORE LAKE·ENGLAND
BASSANO DAM·CANADA
OSHOGBO·NIGERIA
SUKKUR·PAKISTAN
CATALANA·SPAIN
LOWER SIND·PAKISTAN
N'CEMA·RHODESIA
BREADALBANE·SCOTLAND
HOBHOLE·ENGLAND
MONTEVIDEO·URUGUAY
EMBARCADEROS·SPAIN
COFRENTES·SPAIN
VAAL HARTZ WEIR·SOUTH AFRICA
UMGENI·SOUTH AFRICA
POLLAPHUCA·EIRE
INISHCARRA·EIRE
RANSOMES AND RAPIER LIMITED, IPSWICH, ENGLAND

Why does one choose sm?



this is one of the many reasons...

The ratings of a circuit breaker can be validly supported only by suitable type tests proving the circuit breaker behaviour under the worst conditions which must be faced on service.

The MT circuit breakers (see illustration) of SCARPA e MAGNANO underwent, for each service voltage, the type tests required by the I. E. C. International Standards, at the official Laboratory of KEMA, in Holland.

The certificates proving the favourable result of these tests are kept by SCARPA e MAGNANO at the disposal of customers.

SCARPA e MAGNANO

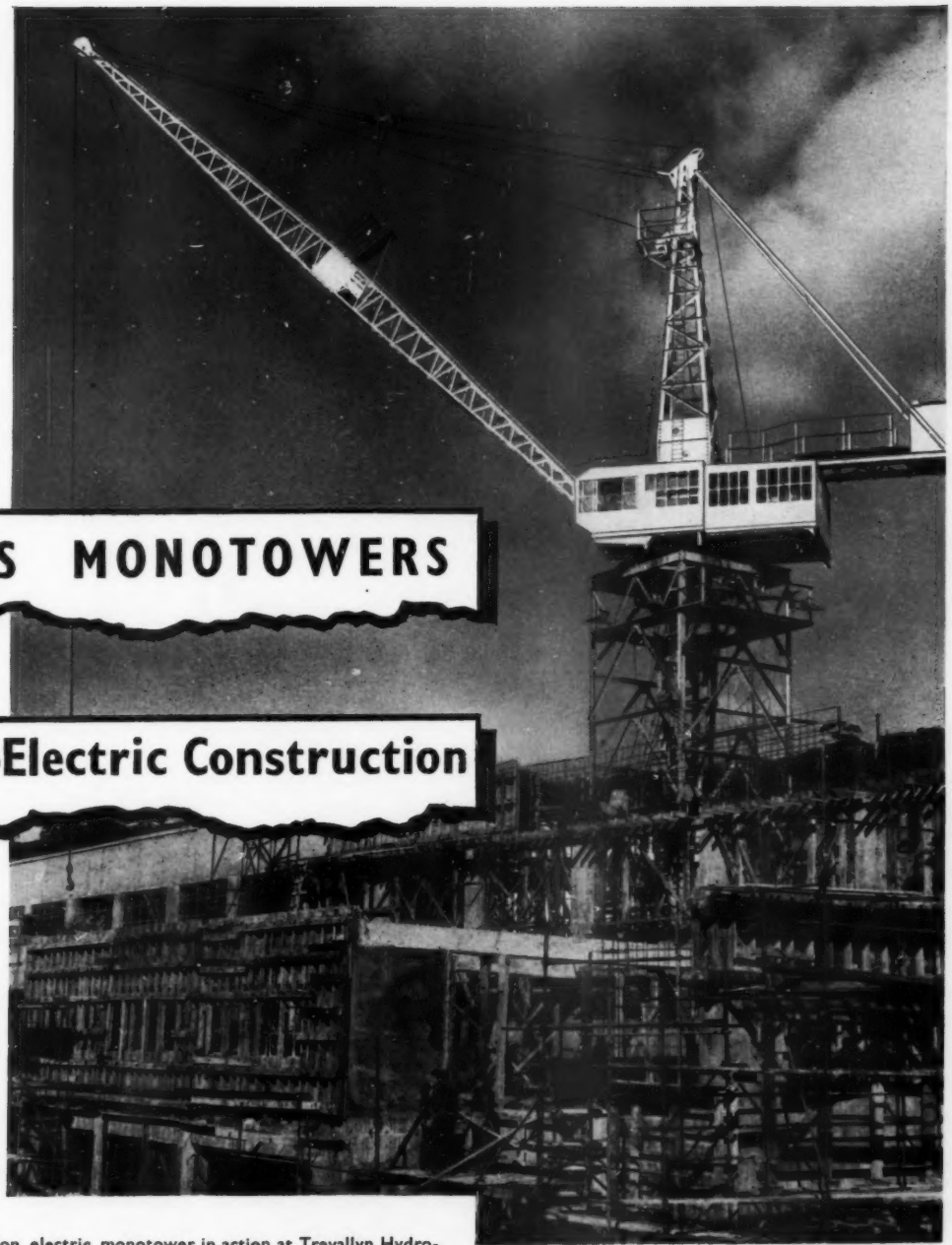
small - oil - volume circuit breakers
metal - enclosed air - insulated switchgear
instrument and protective transformers
isolators
switchboards and control desks

SCARPA e MAGNANO - VIA MANZONI, 12 - MILANO (ITALY)

PLEASE SEND ME INFORMATION ON:

☐ H. V. CIRCUIT BREAKERS ☐ ISOLATORS
☐ M. V. CIRCUIT BREAKERS ☐ INSTRUMENT AND PROTECTIVE TRANSFORMERS

NAME _____ TITLE _____
COMPANY _____
STREET _____ CITY _____ STATE _____



BUTTERS MONOTOWERS

in Hydro-Electric Construction

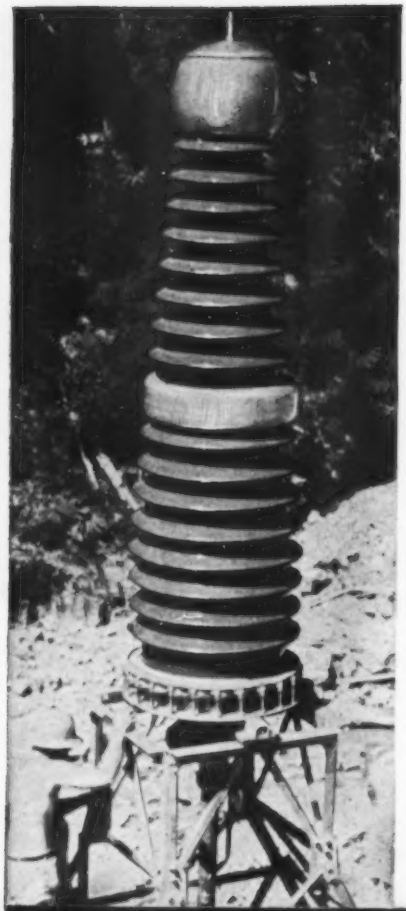
This crane is a 5 ton electric monotower in action at Trevallyn Hydro-Electric Power Station near Launceston, Tasmania. It has a 100 ft. jib, 80 ft. tower, and handles 5 tons at 75 ft. and 1¾ tons at 100 ft. radius. The ideal crane for erection of dams and high buildings generally, with all the dependability of the Butters product.

BUTTERS BROS. & CO. LTD.

MACLELLAN STREET, GLASGOW, S.1.

Telephone: IBROX 1141 (6 lines) *Telegrams: "BUTTERS, GLASGOW."*

AND AT LONDON, BIRMINGHAM & NEWCASTLE



In the Snowy Mountains region of Australia, a great river, the Snowy, and its tributary, the Eucumbene, are being diverted from an easterly course to irrigate the western plains of New South Wales and Victoria. On its journey westward this water will fall more than 2,000ft.—a staggering power potential which, through a chain of hydro electric power stations, will eventually produce enough electricity to pay for the whole vast enterprise. For one of the first of these power stations, the T.1. on the River Tumut, a tributary of the Eucumbene, Pirelli-General have manufactured and installed the highest voltage oil-filled cables ever made in this country. Transmission of power at 330kV. 3 phase 194 M.V.A. (340 amperes phase) along a tunnelled route from an underground generating station to an outdoor switchyard some 1,600ft. distant *on the other side of the River Tumut*

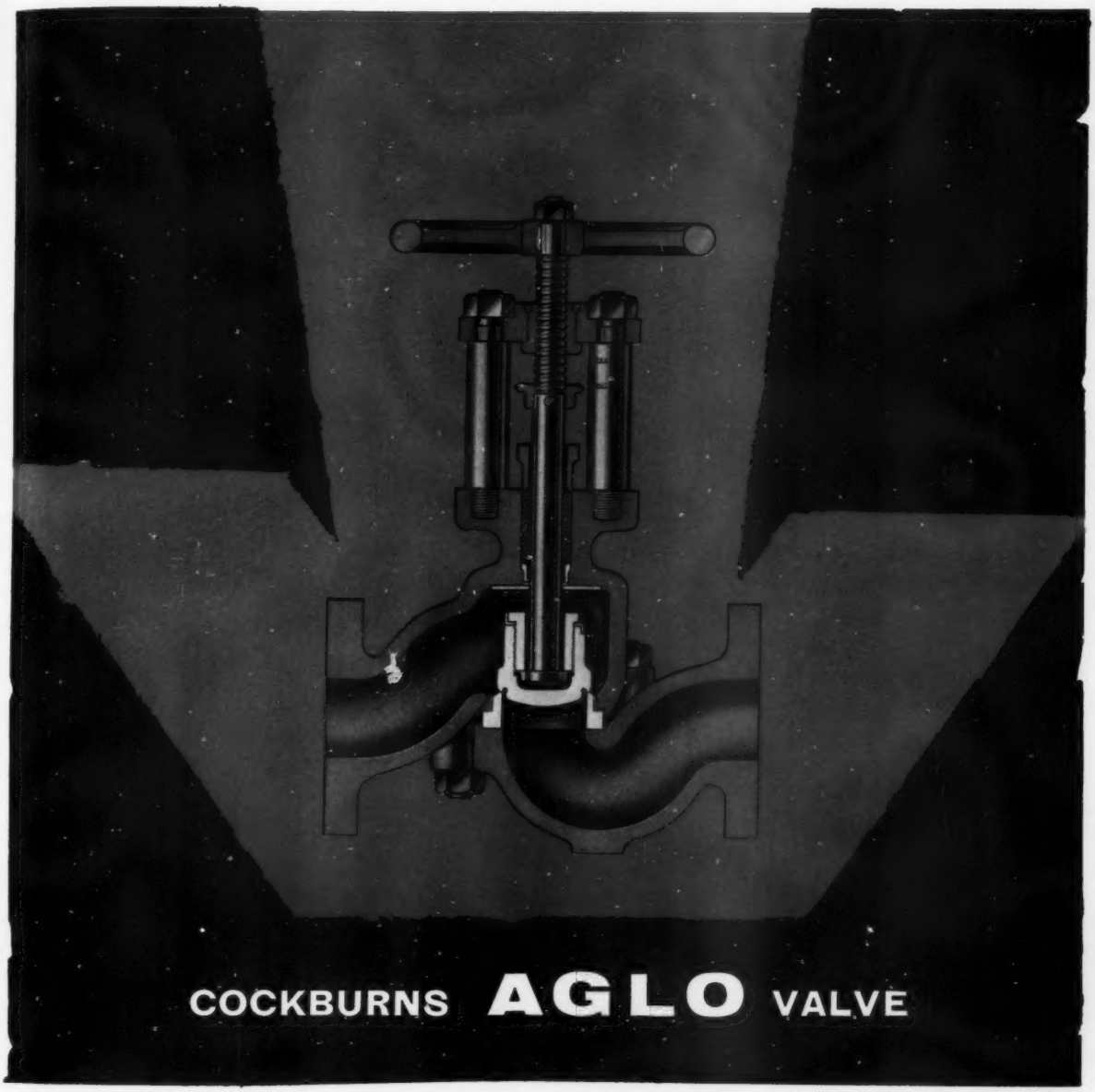
AUSTRALIAN SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY

FIRST with 330kV OIL-FILLED CABLES

proved a formidable undertaking, and the seven cables, all of which were installed in single lengths of 1,625ft. without intermediate joints, were carried on the bridge shown in the photograph. Pirelli-General are proud to announce that their contract to provide a vital link in this great Commonwealth enterprise has now been completed.

pg

PIRELLI-GENERAL
CABLE WORKS LTD · SOUTHAMPTON



COCKBURNS AGLO VALVE

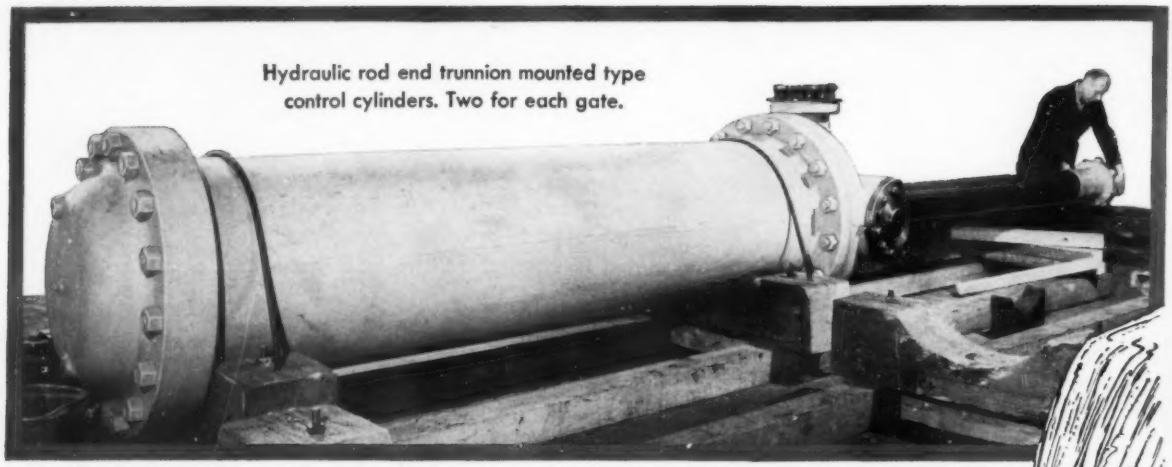
COMPACT IN SIZE ADAPTABLE FOR CONDITIONS

Design Features

Streamline formation minimises pressure drop.
Introduction of separate Adaptor Piece converts to right-angle flow.
Applicability to a wide range of fluid and gas services.
Minimum Maintenance.
Availability in ¾", 1", 1¼", 2", 2½" and 3" sizes.

COCKBURNS LIMITED
Cardonald, Glasgow S.W.1.
London Office: 175 Piccadilly, W.1.
N.E. Depot: Fish Quay, N. Shields.

COCKBURNS (NEDERLAND) N.V.
Kethel, Schiedam, Holland.



Hydraulic rod end trunnion mounted type control cylinders. Two for each gate.

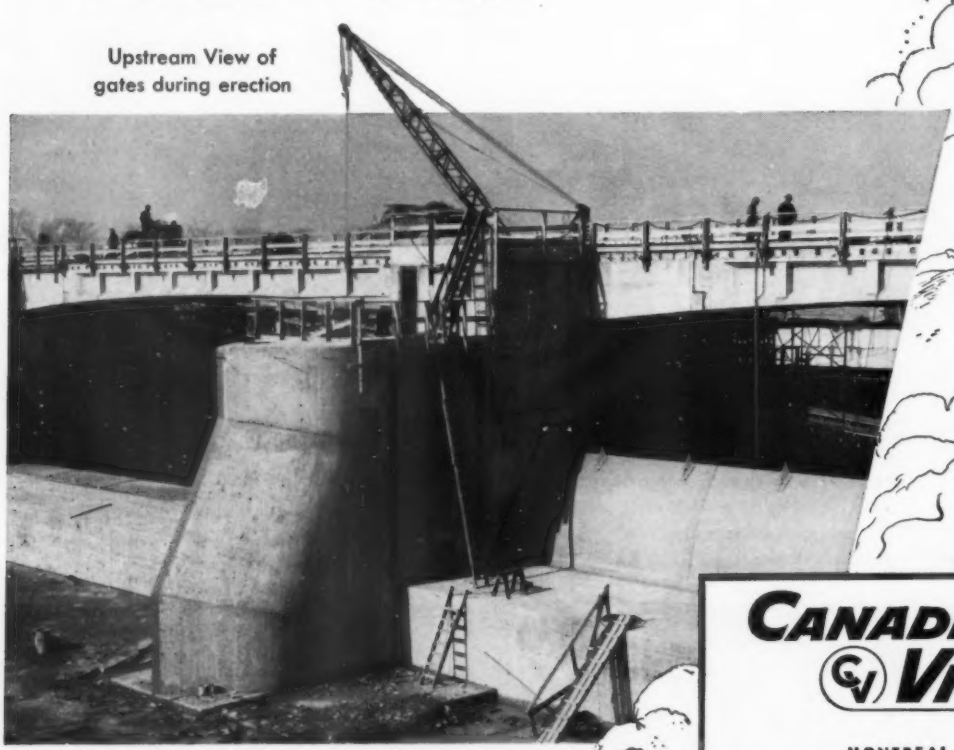
CONTROLLING THE FLOW OF NIAGARA

The flow of Niagara, one of Canada's greatest sources of electric power, is controlled by Vickers-built submersible gates of the "fishbelly" type.

Working with the M.A.N. Company, a Canadian Vickers associate, who designed the 100 ft. wide section welded gates, thirteen gates were supplied along with twenty-six servomotors and thirteen pumping sets which were entirely engineered by Canadian Vickers.

These gates are another example of the precise engineering that goes into all Vickers-built water control equipment.

Upstream View of gates during erection



CANADIAN VICKERS LIMITED

MONTREAL • TORONTO

CANADIAN MEMBER OF THE VICKERS GROUP

Reinforced Concrete Pipes, ordinary and pre-stressed in all diameters and pressures

Pre-stressed reinforced concrete pipe, diameter 3.30m. pressure 9 atm. Brunico hydro-electric power station, Italy. Soc. Montecatini

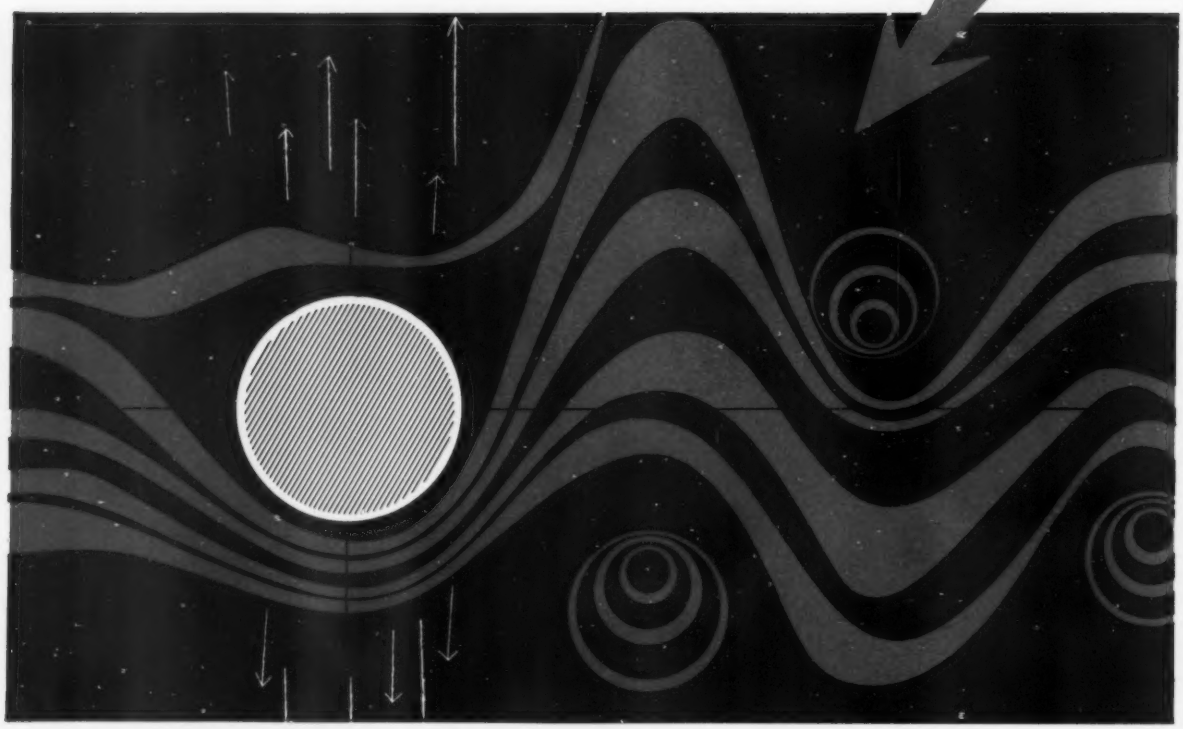
SACAIM

Soc. p. Az. Cementi Armati Ing. Mantelli

VENICE (ITALY) - Accademia 979/A - Telephone 85.060

Question to Power Line Builders:

Is this your problem?



It could be. The problem of vibrating conductors is still the subject of world-wide investigation. It is a difficult problem because of the many factors involved—climate and the local topography have to be considered, as well as the manner of construction of the power line.

As transmission voltages are raised, too, the problem increases. The large-diameter conductors which are required are more prone to vibrate, since they expose a greater surface to the wind. Having greater tensile strength, they can also be strung more tightly—and higher tension means increased vibration.

The worst vibrations may be caused by very light winds, and in countries where icing is no problem, the regulations may permit undesirably high tensions. Dampers, armour rods, and proper design of the suspension clamps may reduce or eliminate conductor damage resulting from vibration—but in striking a balance between economy and safety, the question is how to determine the most suitable tensioning.

In Sweden vibration problems have been given especial attention, and Svenska Metallverken is now making available the collective know-how which has been acquired on this subject. But whatever your problem, it will pay to consider the advanced technical service which goes with purchases of Feral Cable—*reliable* Swedish ACSR.

NEW TECHNICAL INFORMATION. A special survey of the vibration problem has been prepared for us by a leading expert—an engineer of the Swedish State Power Board who is also chairman of the international committee which is presently studying the matter. Besides incorporating the latest findings, the survey gives recommendations as to suitable practice. Copies of this publication, as well as advice on specific problems, supplied by Swedish experts, can be obtained through Svenska Metallverken, Feral Cable Division.

Vibration Damper of the type generally used in Sweden. Developed by the State Power Board, it acts through loose weights. It is practically unbreakable, relatively cheap, and has no natural frequency which might aggravate conductor vibrations.

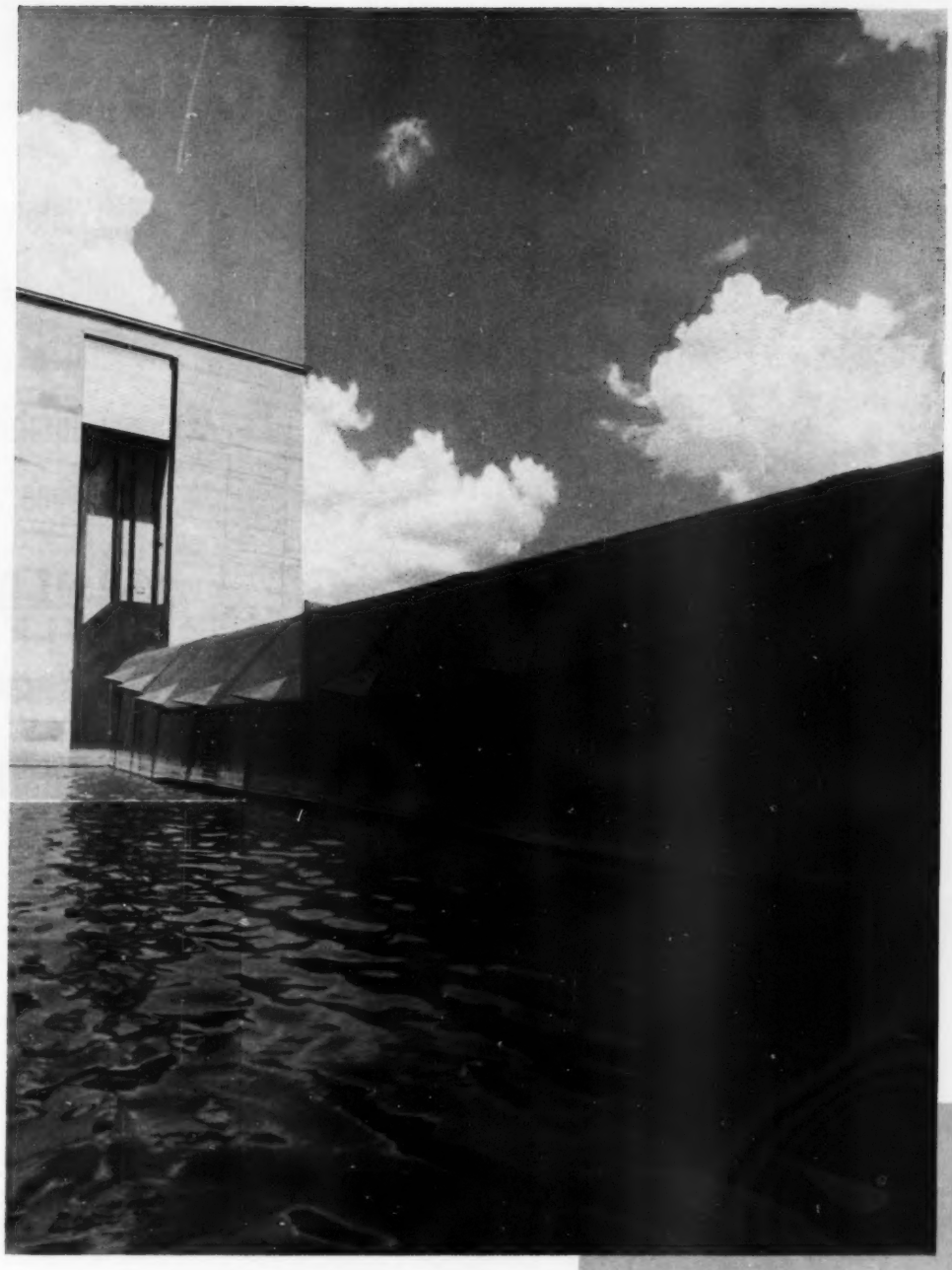
When planning power lines, consult

SVENSKA METALLVERKEN

Manufacturers of Feral Cable

FERAL CABLE DIVISION SWEDEN VÄSTERÅS · SWEDEN

M·A·N



In hydro-power plants, minute regulation of the water level is an important feature best achieved by discharging the upstream water over the gate. The M.A.N. submersible sluice gate is particularly suited to that requirement. Illustration shows sluice gate of 30 m clear width and 4.85 m water head supplied for Kitzingen Weir Plant / River Main. Gate was designed to be lowered 1.3 m.

YDRAULIC STRUCTURES

ASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORK

USTAVSBURG/HESSEN (GERMANY) REPRESENTATIVES IN ALL COUNTRIE

AEI CABLES

New Yellow & Black Reel – Symbol of New Combined Resources

HENLEY CABLES

LIVERPOOL CABLES

SIEMENS EDISWAN

Three great companies combine their tremendous experience, capacity and enthusiasm to offer a cable service which is unsurpassed. The new yellow and black reel symbolises their new united resources. Backing them is the massive research and development organisation of AEI. For this effective new combination your cable or wire requirements will never be too big or too small—too simple or too complex. **YOU CAN RELY ON AEI**

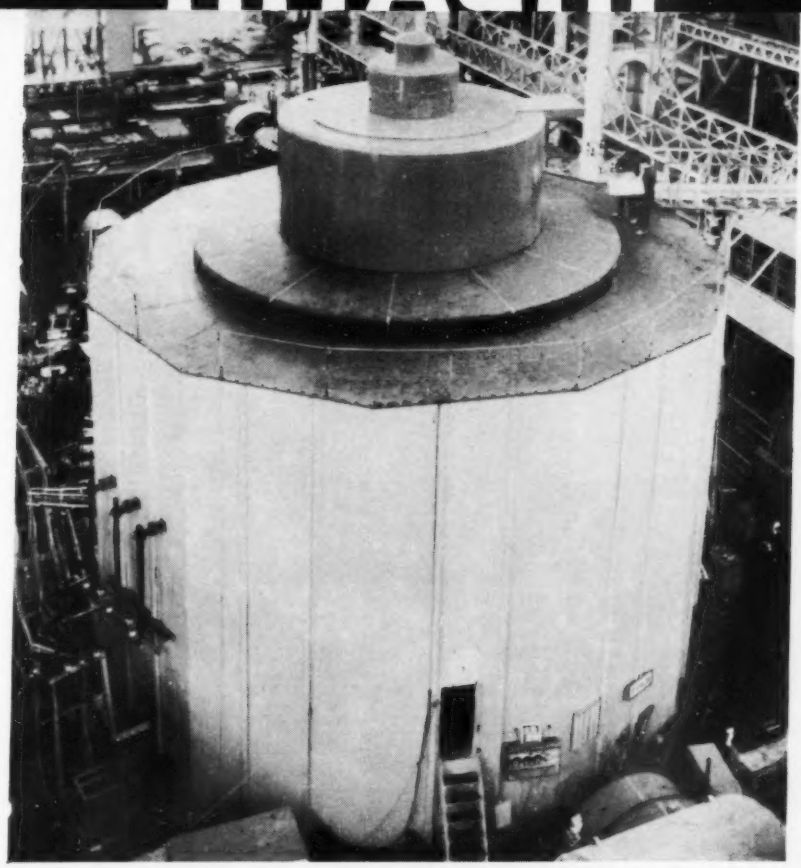
AEI

CABLE DIVISION

Associated Electrical Industries Limited

51-53 Hatton Garden · London · EC1 *Phone: CHAncery 6822*

HITACHI



125,000 kVA AC Generators for Miboro Power Station

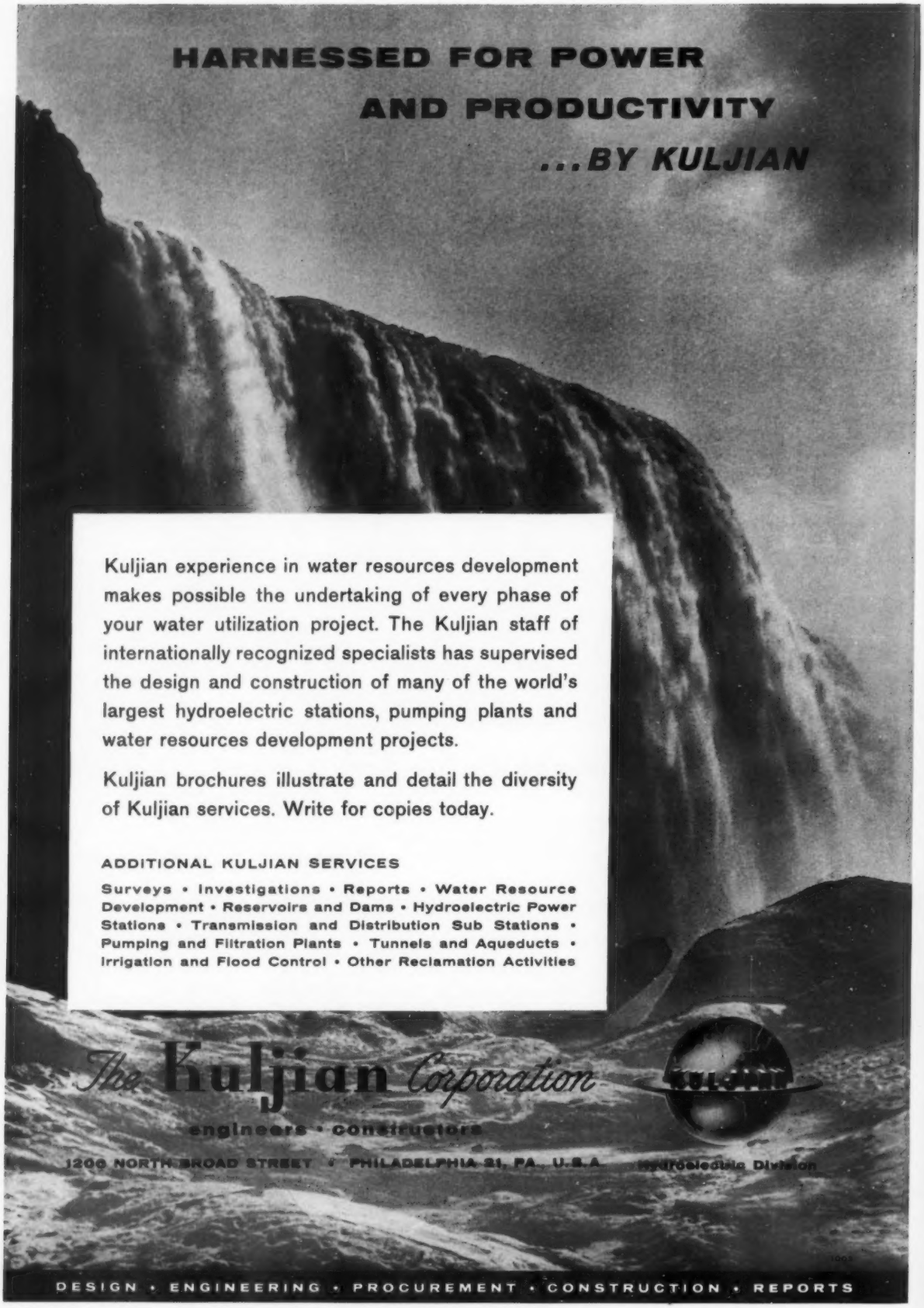
Hitachi has recently completed two 125,000 kVA A.C. generators for the Miboro Power Station in Japan. These have a comparatively high speed (225 r.p.m.) and present a high-torsoed appearance as shown in the photograph.

Since these generators were designed for a rated voltage of 16,500 volts and, in this respect, represent the first such attempt in Japan, particular care was taken in the corona-shielding and impulse resistance of the stator winding.

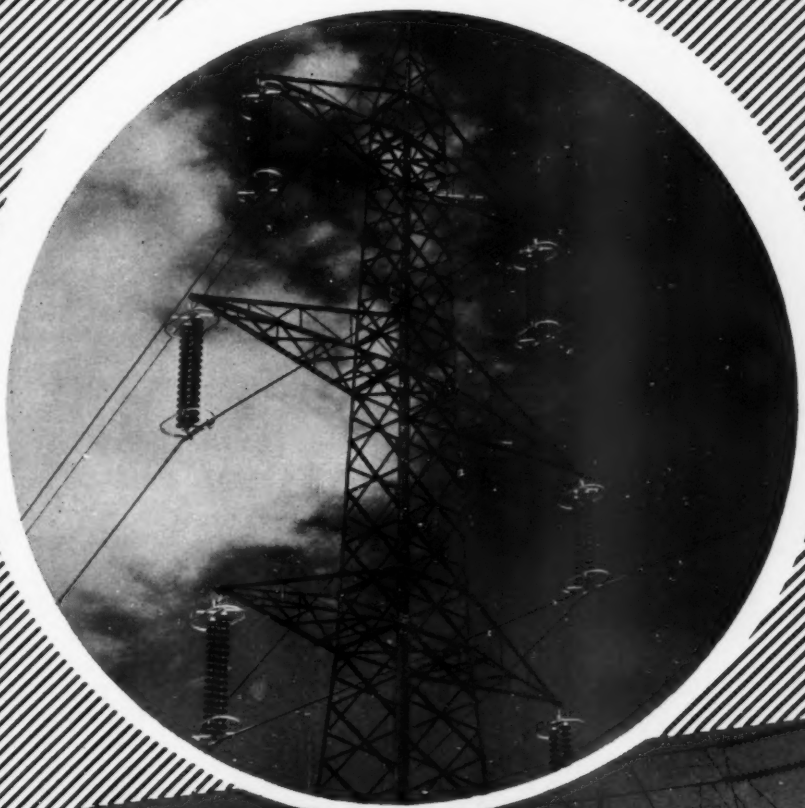
The Miboro Power Station is located underground and the generators will be installed in the generator pits, with only the exciters appearing above the floor. The exciters are of the enclosed ventilated type and share the same cooling air circulation system with the generators.

Each of the generators is rated at 60 cycles, 225 r.p.m. and 0.9 power factor but is also capable of operating at 50 cycles, 187.5 r.p.m. and 1.0 power factor. They are to be driven by the 137,500 kW vertical Francis Turbines completed last September at the Hitachi Works.

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO


HARNESSED FOR POWER
AND PRODUCTIVITY
...BY KULJIAN
Kuljian experience in water resources development makes possible the undertaking of every phase of your water utilization project. The Kuljian staff of internationally recognized specialists has supervised the design and construction of many of the world's largest hydroelectric stations, pumping plants and water resources development projects.
Kuljian brochures illustrate and detail the diversity of Kuljian services. Write for copies today.
ADDITIONAL KULJIAN SERVICES
Surveys • Investigations • Reports • Water Resource Development • Reservoirs and Dams • Hydroelectric Power Stations • Transmission and Distribution Sub Stations • Pumping and Filtration Plants • Tunnels and Aqueducts • Irrigation and Flood Control • Other Reclamation Activities
The Kuljian Corporation
engineers • constructors
1200 NORTH BROAD STREET • PHILADELPHIA 21, PA., U.S.A.
Hydroelectric Division
DESIGN • ENGINEERING • PROCUREMENT • CONSTRUCTION • REPORTS

SALVI

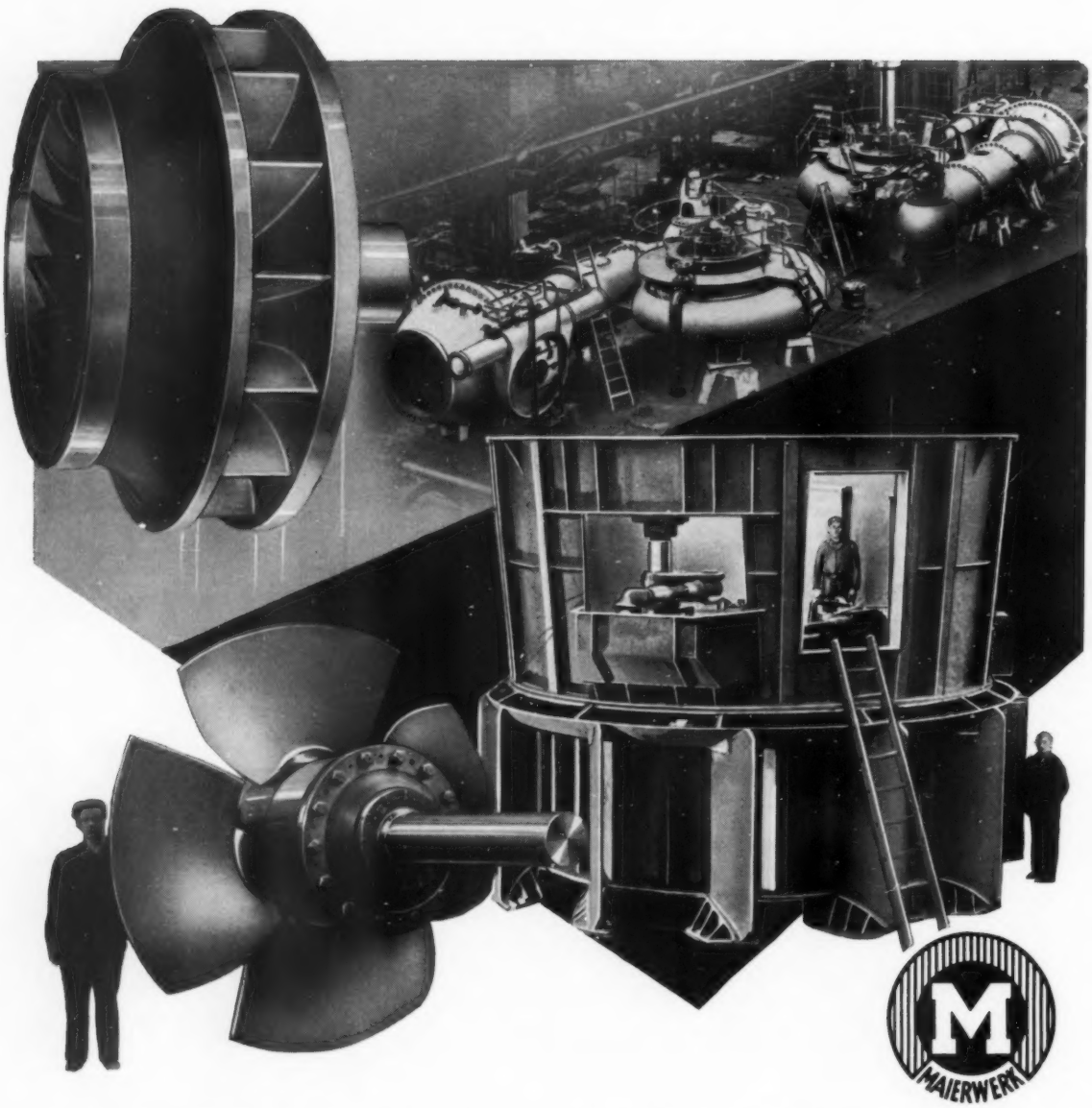


For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints. The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES (EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

THE ENGLISH SALVI COMPANY LTD., West Road, Northumberland Park, Tottenham, London, N.17

Telephone: TOTTENHAM 6611



The upper photographs represent **High-pressure Francis Turbines** in our workshops complete with **spherical valves** as well as a corresponding runner of stainless cast steel, cast in one piece.

A Kaplan Turbine in our erection workshops with a corresponding runner also of stainless steel, is shown below.

Every one of our runners is carefully tested in our laboratories as well from the hydraulic point of view as with regard to security against cavitation.

MASCHINENFABRIK B. MAIER

BRACKWEDE GERMANY (WESTFALEN)

CABLES: MAIERWERK-BIELEFELD · CODES: RUDOLF MOSSE CODE/ALPHA-CODE

1947 TO 1958

44,948 TONS OF PENSTOCKS

DESIGNED · SUPPLIED · ERECTED

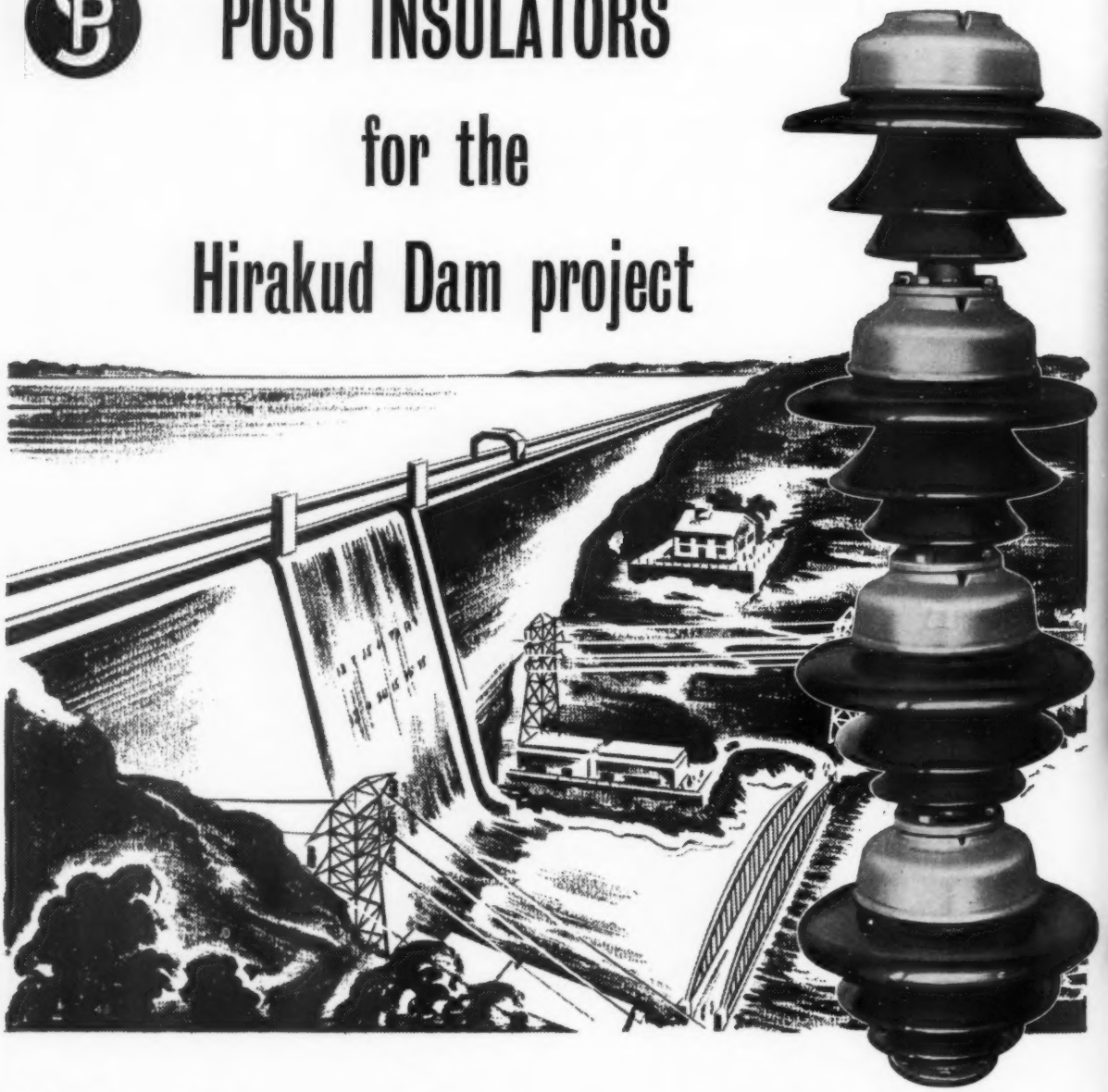
EXTRACTS FROM OUR REFERENCE LIST

Serial No.	Name of Plant and Country		Head in m	Weight in tons	Diameters in m/m	Length in m	Plate thickness in m/m	No. lines	When ordered
261	Grønsdal	Norway	177	302	2200–1900	255	12–23	1	1947
262	Dale III	„	311	737	2000–1400	700	12–35	1	„
263	Grytten	„	424	374	900–800	1070	8–22	1	„
264	Maudal II	„	370	889	1650–1450	900	12–30	1	„
268	Skjerka II	„	340	1502	2100–1650	1240	22	1	„
272	Sand	„	320	181	500–450	1650	7–10	1	„
273	Søre Sunnmøre	„	377	235	1100–850	682	9–23	1	„
275	Glomfjord (Flow Lines)	„	—	368	550	3037	7	1	„
277	Pykara IV	India	936	3000	1067–991	3025	12–49	1	„
283	Lund	Norway	251	190	700–550	1112	8–10	1	1948
284	Vadheim II	„	313	222	1050–850	676	9–17	1	„
286	Festa	„	210	194	1300–1200	407	10–14	1	„
288	Kåven	„	117	180	1600–1500	360	10–12	1	„
290	Vinstra I	„	447	1020	2400–2200	387	14	1	1949
291	Tafjord	„	400	400	1750	608	8–14	1	„
292	Åbjøra	„	439	739	2300–900	666	12–35	1	„
293	Poringalkuthu	India	181	2000	2590–1320	887	11–30	3	„
294	Machkund	„	260	1450	1600–1450	500	11–32	3	„
298	Sueva I	Colombia	233	88	800–100	514	5–10	1	1951
299	Sueva II	„	187	135	1200–1000	509	6–12	1	„
302	Trevallyn	Tasmania	163	470	4420–1727	152	24	1	1952
304	Aura II-C	Norway	295	396	2200	416	12–44	1	„
305	Aura II-D	„	744	1112	1600	1212	12–44	1	„
306	Røssåga	„	247	1237	3400–3000	398	13–26	2	1953
309	Nore	„	368	337	1800–1300	475	12–34	1	1954
313	Mocorongo	Colombia	331	657	2000–1736	1015	9–21	1	„
316	Hardeland	Norway	322	272	1300–1000	879	8–15	1	1955
319	Poringalkutha	India	181	480	2590–1320	887	11–30	1	„
320	Hjartdøla	Norway	587	1061	2600–1500	1145	10–49	1	1956
321	Machkund 2nd Stage	India	260	1500	1600–1450	500	11–32	3	„
322	Bhakra (Bulk Heads)	„	—	60	4450	—	17,5	–	„
323	Kaldåga	Norway	566	789	1300–1000	1803	8–23	1	„
329	Sande	„	90	225	600	3000	5	1	„
332	Gjuva	„	390	206	1200–800	875	8–14	1	„
334	Innset	„	187	400	3200–2000	253	14–22	1	1957
337	Neriamangalam	India	224	900	3353–1600	1359	12–17	1	1958
338	Kiewa I	Australia	—	5	1912–864	—	20	–	„
339	Fortun II	Norway	873	112	1600–1300	75	30–61	1	„
340	Vrenga	„	379	440	1300–900	1568	8–11	1	„
341	Tyin II	„	1009	1485	1600–1200	1857	10–47	1	„

FERRUM MONTAGE A/S

OSLO · NORWAY

POST INSULATORS for the Hirakud Dam project



S.P.P. Post Insulators were supplied for the 132kV. outdoor switchgear on the Hirakud Dam Project.

S.P.P. Post insulators have also been used on all the major hydro-electric projects in India, including the following:—

Damodar Valley Corporation
U.P. Government
Madras Government
Mysore Government
Travancore—
Cochin Government
Bombay Grid Scheme
Jog Falls Scheme
Machkund Scheme
North Calcutta Scheme
Pallivasal Scheme
Tungabhadra Scheme
Kunda, Madura, Mettur Dam, Moyar, Papanasam and many other substations on the Madras Grid.

STEATITE & PORCELAIN PRODUCTS LTD.

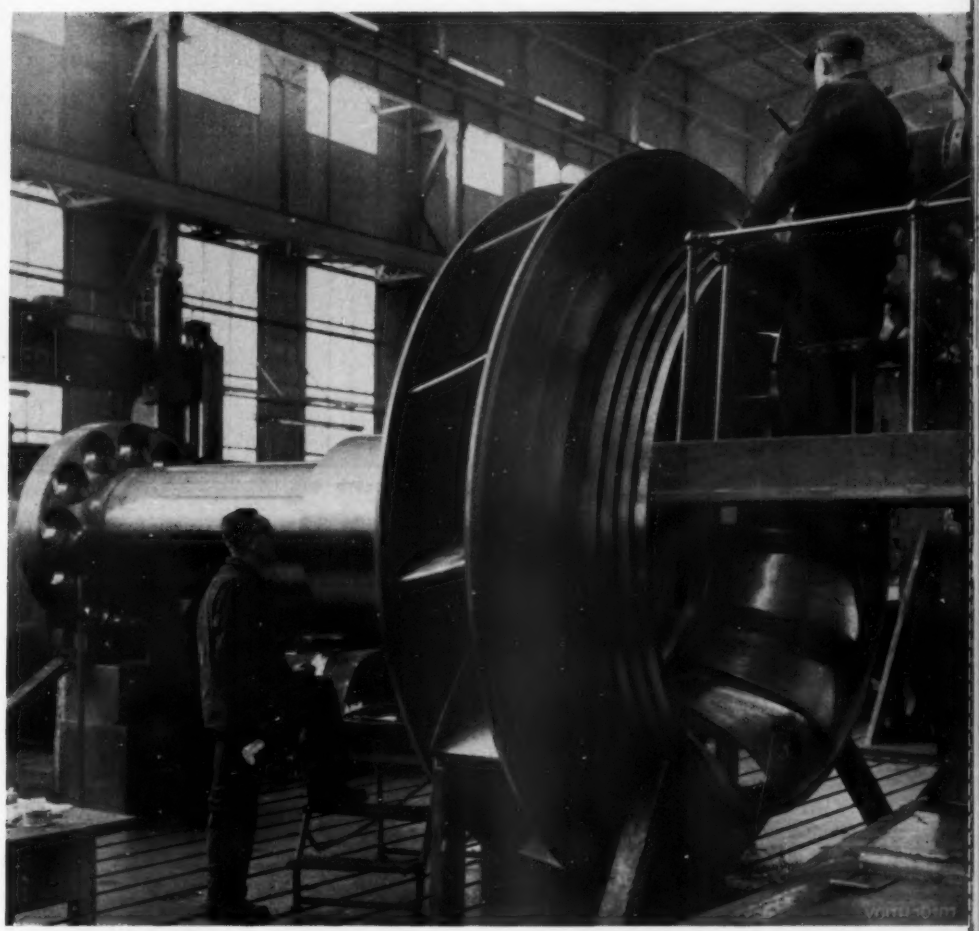
Stourport-on-Severn, Worcestershire. Telephone : Stourport 2271. Telegrams : Steatain, Stourport

SP94A

FRANCIS RUNNER

rated at 163,000 h.p. under 870 ft. head, in the workshops of Voith-Heidenheim.

One of the two 11 ft. 4 in. Francis runners on one of our vertical boring mills in our large high headroom turbine erection shop (photo). The coupling bolt holes in shaft flange and runner crown are being jointly drilled. After balancing the runner will be shipped to Yugoslavia where in the SPLIT POWER STATION two such 163,000 h.p. Voith Francis spiral turbines will be installed.



J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY

ALLIS-CHALMERS

One of three 96-inch **Howell-Bunger** valves in operation at the U. S. Engineers Mud Mountain Dam, White River, Wash.

2 ways to air-cushion a big splash

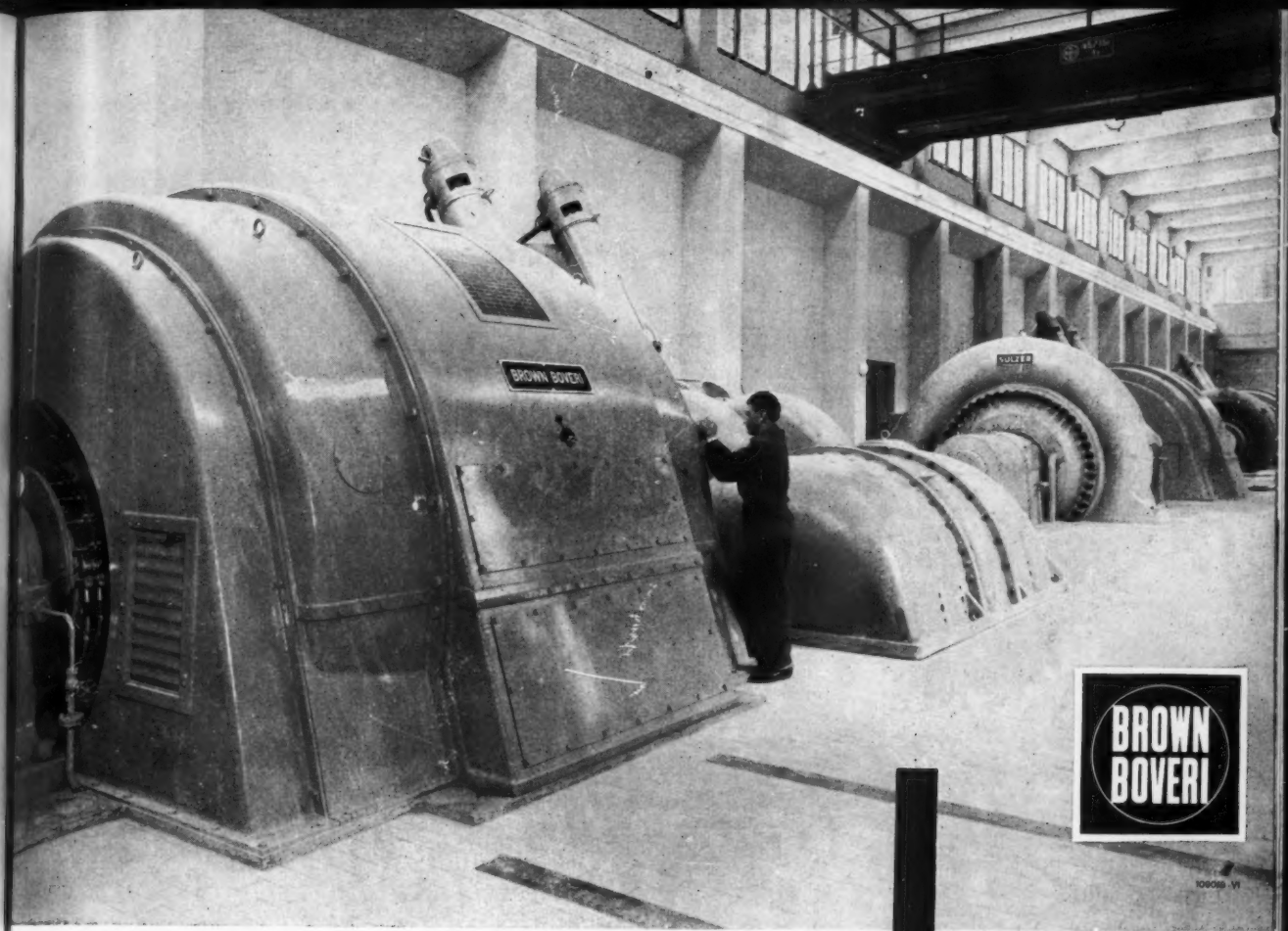
...and provide easy regulation of free discharge

***Howell-Bunger* valves** produce an expanding, aerated water jet that dissipates tremendous energy with minimum erosion and cavitation — and virtually no vibration. They're ideal for free discharge with high to low heads, into atmosphere or water. Lowest in initial cost... economical to install (need pipe line or conduit of *minimum* size). Only one moving part in contact with flow.

***Ring-Jet* valves** yield a concentrated, aerated jet, perfect for locations requiring reduced spray. A logical development from the *Howell-Bunger* valve, they offer many parallel advantages ... are equally suited to high and low heads.

Only Allis-Chalmers is geared to equip complete hydro installations — turbines, generators and auxiliaries. Contact our office in your area for information. Or write ***Allis-Chalmers,*** *Hydraulic Division, York, Pennsylvania.* A-1256

One of two RING JET valves used for irrigation bypass from Tulloch Dam, California.



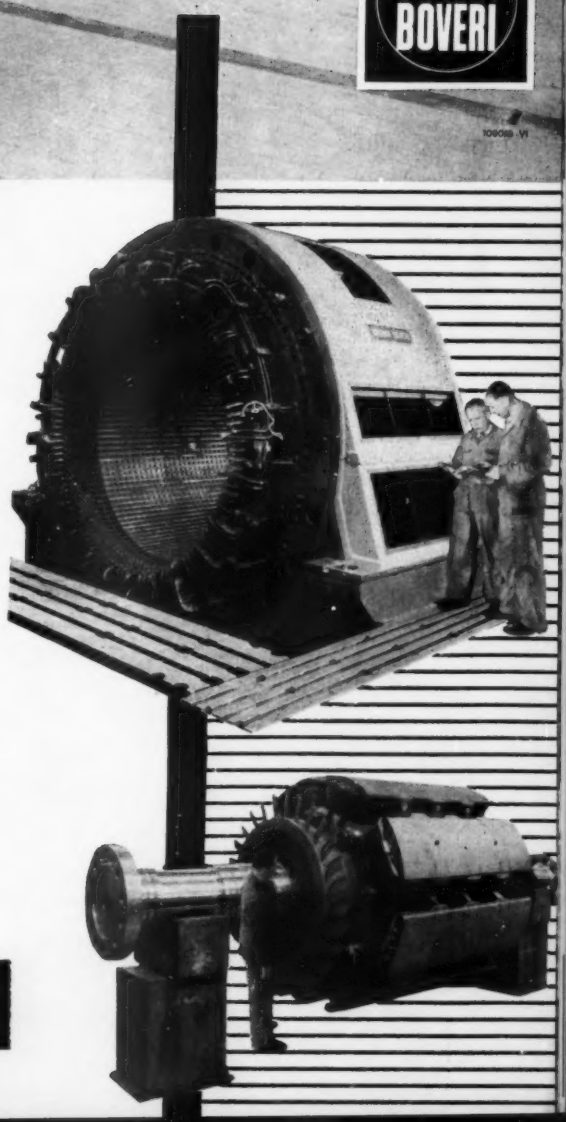
Machine room in the Motec power station of the Gougra Power Co., Switzerland with three 29.4-MVA generators for 750 rev/min 50 cls.

Key Products of Swiss Industry

Large alternators for high and low-head hydro-electric and thermal stations

Based on methodical research and years of experience we construct alternators for highest known outputs.

Our production programme includes:
Equipment for hydraulic generating plants • Control and protective gear for generators • Transformers, Airblast circuit-breakers and instrument transformers up to 400 kV • Electric motors • Electric furnaces • Welding machines • Transmitting and rectifier tubes • Transmitters • Carrier equipment for communication and control over power lines

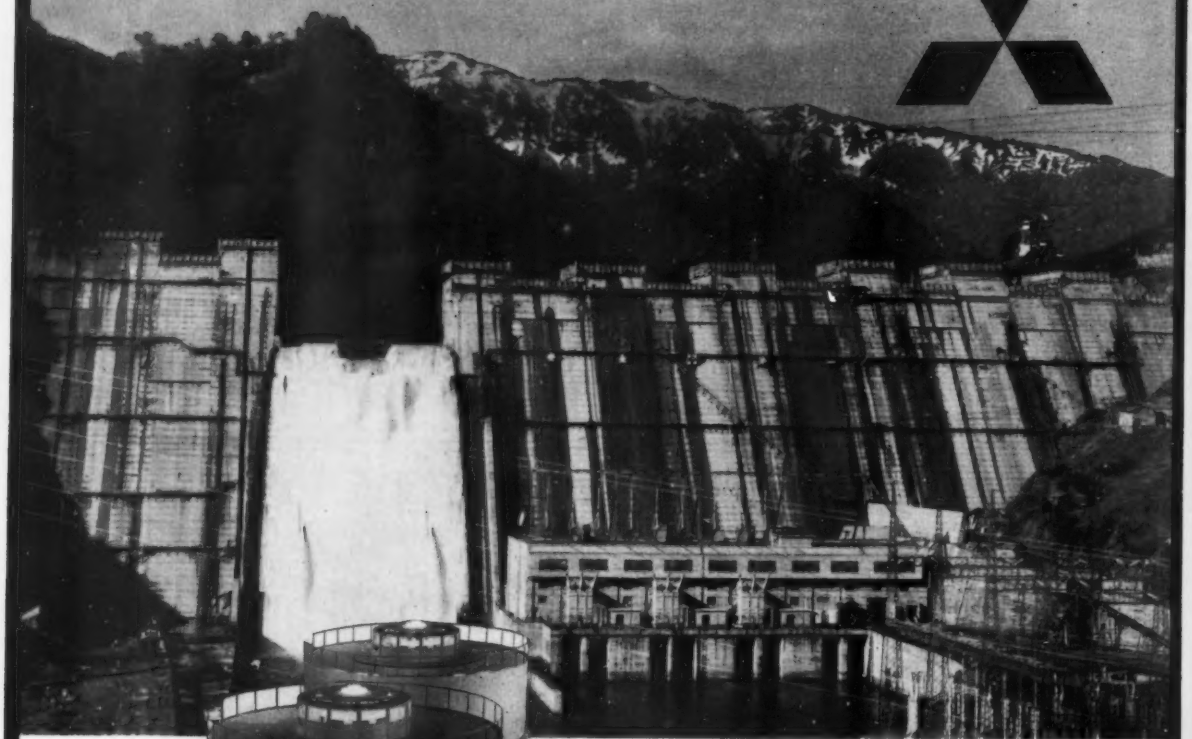


BROWN BOVERI

BROWN, BOVERI & CO., LTD., BADEN • SWITZERLAND

Representatives in most countries

MITSUBISHI
ELECTRIC builds your easy life



105,000 kVA Water-wheel Generator

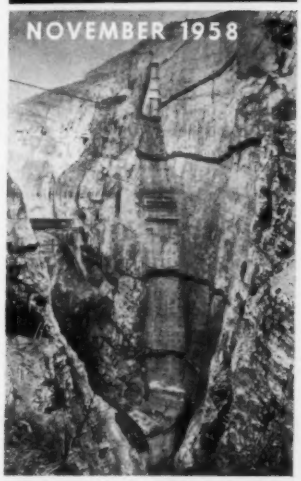
Today an easy life is no luxury... owing to electric power.

Mitsubishi Electric engineers, workers... all play important roles in making your life more comfortable... manufacturing every type of electrical equipment from giant generators and transformers to small home appliances that offer an easier life... the electric way.

For unmatched experience and the widest record of achievements, look to the THREE DIAMONDS of the Mitsubishi Brand. They represent QUALITY and INTEGRITY.

MITSUBISHI ELECTRIC MANUFACTURING COMPANY

Head Office: Tokyo Building, Marunouchi, Tokyo Cable Address: MELCO TOKYO



S.A.D.E.

SOCIETA ADRIATICA DI ELETTRICITA'
VENEZIA – ITALY

VAJONT

PIAVE – BOITE – VAJONT
HYDRO-ELECTRIC SCHEME

CUPOLA DAM
MAX. HEIGHT 873 ft.
CREST LENGTH 623 ft.
CONCRETING PROGRESS
NOVEMBER 1959

DR. ING.
G. TORNO & C.
SOC. P. AZ.

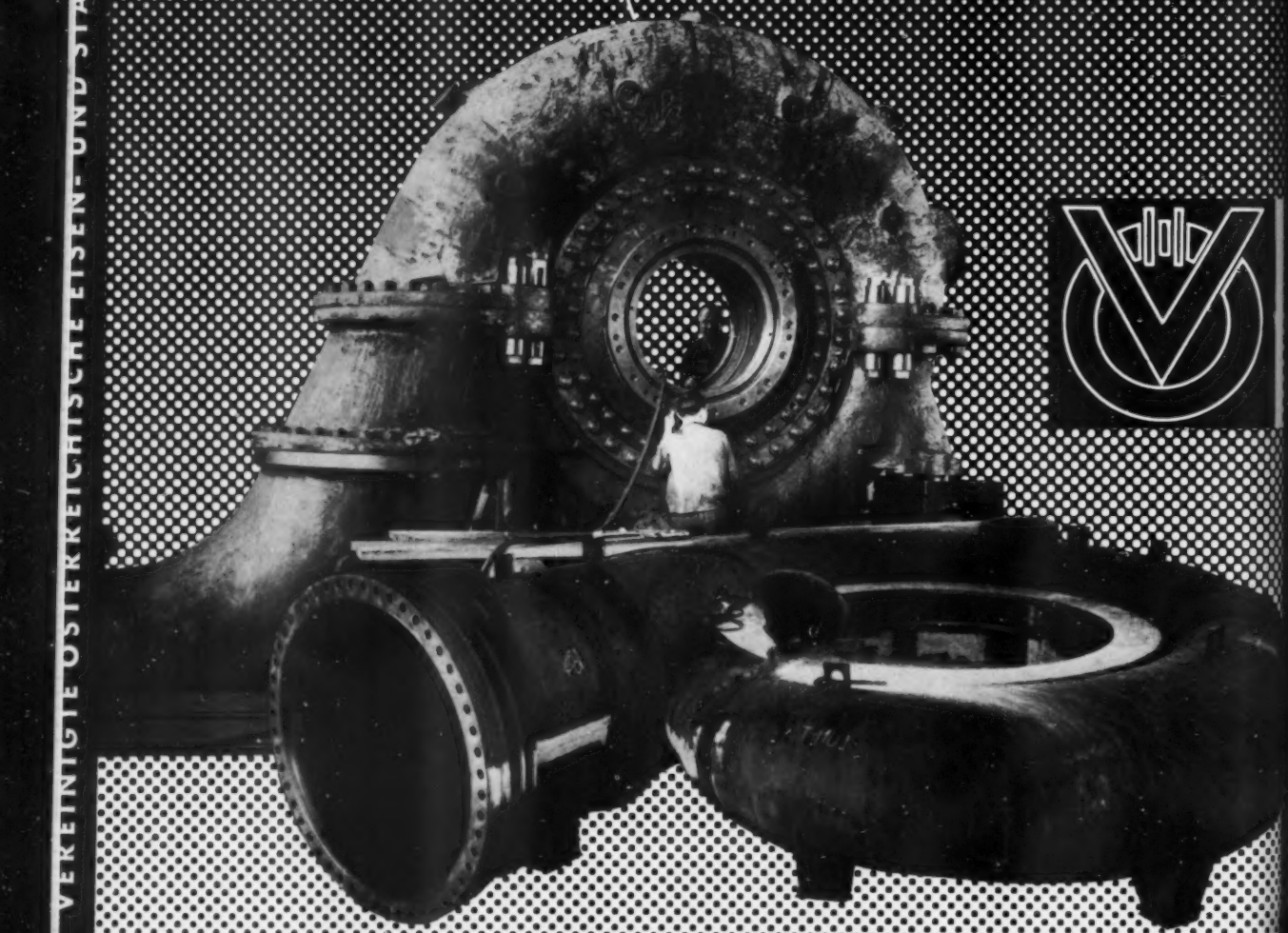
BUILDING & CIVIL
ENGINEERING CONTRACTORS
& CONSULTANTS
7, VIA ALBRICCI – MILANO – ITALY

VÖEST

VEREINIGTE ÖSTERREICHISCHE EISEN- UND STAHLWERKE, LINZ-DONAU, AUSTRIA

Hydraulic Turbines, Spherical and Butterfly Valves

Licensed by Baldwin-Lima-Hamilton Corp.
Philadelphia, U.S.A.



VER

VÖEST

HYDRAULIC STEEL CONSTRUCTION

Steel structures for weirs and loch gates of every type, including the required auxiliary equipment; mechanical and hydraulic drives hereto sprocket chains; trash rake cleaning machines; weir cranes.

VEREINIGTE ÖSTERR. EISEN- UND STAHLWERKE, LINZ-DONAU

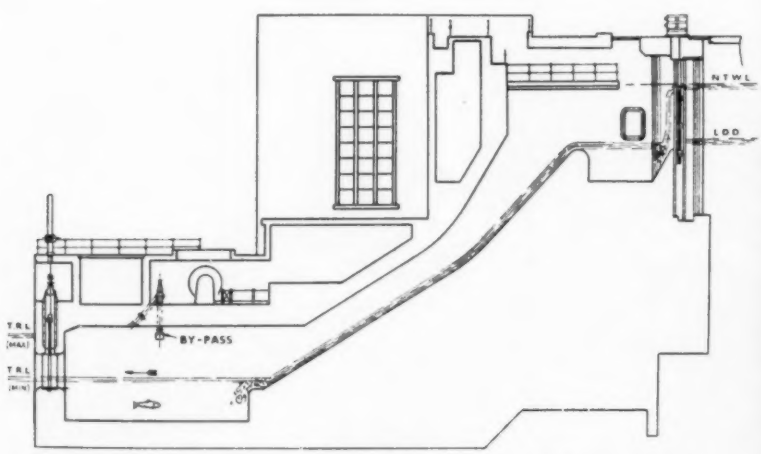
GLENFIELD FISH LIFTS

for Dams and elsewhere

The Glenfield style of hydraulic fish elevator is now an established part of Hydro-electric practice.

It enables migratory fish to pass upstream or downstream of dams and other obstructions under virtually natural conditions with the minimum of effort, by means that effect considerable savings of funds and improvement of general amenities. In operation it is essentially automatic and can be adjusted to any desired time cycle to suit prevailing conditions.

The photograph, taken at a dam in the Scottish Highlands, shows a running salmon leaping through the upper gate opening of a fish lift.



The arrangement of a Glenfield Fish Lift incorporated in the structure of a power station in the Highlands

Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Head Office and Works: KILMARNOCK · SCOTLAND

ESCHER WYSS
turbines near the Arctic Circle

The 83,400 HP Kaplan turbines for Pirttikoski Power Station in Finland represent another example of our activities as suppliers of Hydraulic Installations throughout the world. These units are designed to operate at 115.4 rpm under 29 metres head with 232 cub. m/sec. developing unit outputs of 83,400 HP.

Escher Wyss Ltd. Zurich/Switzerland

BUILDING FOR POWER

Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes.

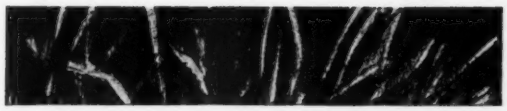
They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

Huwood Conveyors

HUGH WOOD & CO. LTD.

Head Office and Factories
GATESHEAD - ON - TYNE, 11
Telegrams: Huwood, Gateshead. Telephone: Low Fell 76083 (5 lines).

Industrial and Export Office
ROYAL LONDON HOUSE, FINSBURY SQUARE, LONDON, E.C.2
Telegrams: Huwood Stock, London. Telephone: Monarch 3273 (4 lines).

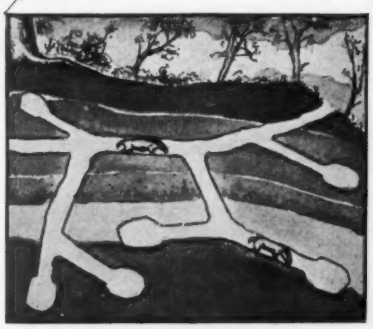


Underground movement

A long tunneller and a strong tunneller, the badger builds himself an intricate web of passages and dens in which to evade pursuit or retire from the noisy world outside.

It's a paradox of progress that man too—in getting even further away from nature—is going more and more underground. Tunnels for hydro-electric schemes, underground power houses—these and many other engineering feats are the work of man the tunneller—a skill which we have developed into a fine art. * *

* * In driving 40 miles of tunnels for the North of Scotland Hydro-Electric Board, Mitchell Construction captured and hold the World high speed rock-tunnelling record and constructed the first major underground power station in Britain.



Many of these badger 'sets' have been enlarged and improved through successive generations and may extend for hundreds of feet into a hillside.

MITCHELL CONSTRUCTION

Building and Civil Engineering Contractors

THE MITCHELL CONSTRUCTION COMPANY LIMITED

WHARF WORKS · PETERBOROUGH

P.2984

EDMUND NUTTALL

Civil
Engineering
Contractors

Telephone
Sloane: 0036

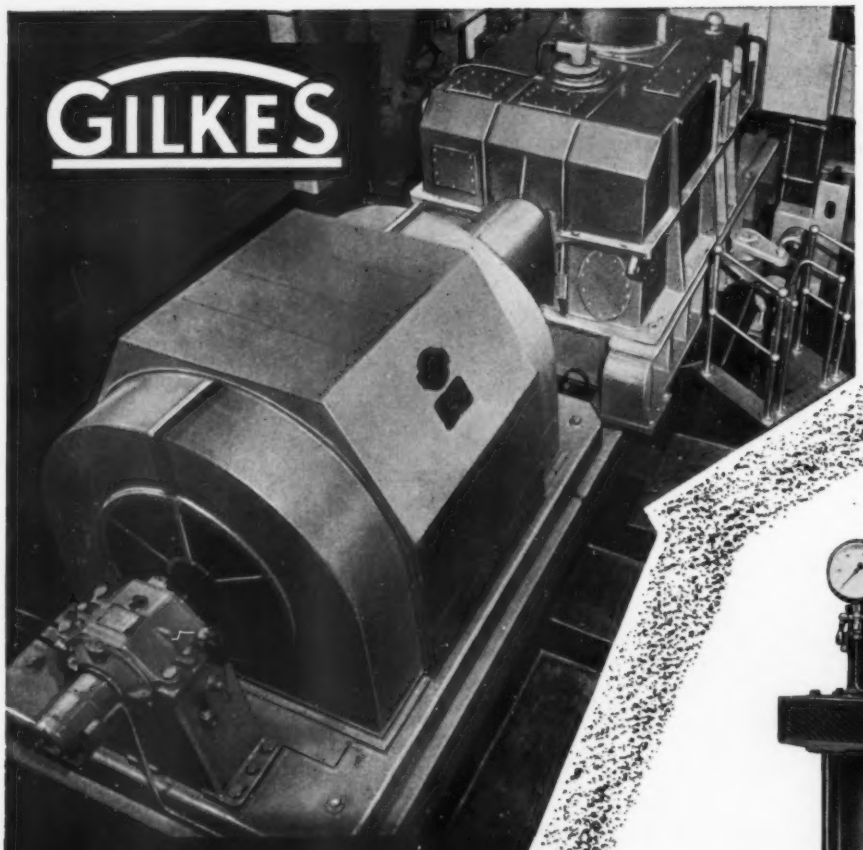
Edmund Nuttall
specialise
in the construction
of civil engineering
works of the larger
kind.
They have built
some of the
biggest
Docks
Dams
and Tunnels
in use
in the world
today.

Edmund Nuttall are the contractors to the Dartford Tunnel now under construction.

EDMUND NUTTALL, SONS & CO. (LONDON) LTD., 22 GROSVENOR GARDENS, LONDON S.W.1.

KVÆRNER
Now under construction—Four turbines
for Tokke 1 Power Plant, Norway.
Head - - 395 metres (1,200 ft.)
Output each - - - 150,000 H.P.
Revolutions - - - - - - - - 375
Weight of Spiral Casing 110 tons
A. S. KVÆRNER BRUG, OSLO NORWAY

GILKES



Left:
The North of Scotland Hydro-Electric Board's Mullardoch underground power station, Glen Affric. This contains a 3,600 horsepower, vertical shaft GILKES Francis turbine driving a 2,400kW Bruce Peebles induction generator through a speed increasing gear unit.

ASYNCHRONOUS HYDRO-ELECTRIC UNITS

for all heads and outputs

Suitable for remote controlled or fully automatic installations, the water turbine driven induction generator provides a simple and economic source of power for operation in conjuction with conventional synchronous plant.

Gilkes specialise in the manufacture of asynchronous hydro-electric plant and have a wide experience in the design of all types of unit.

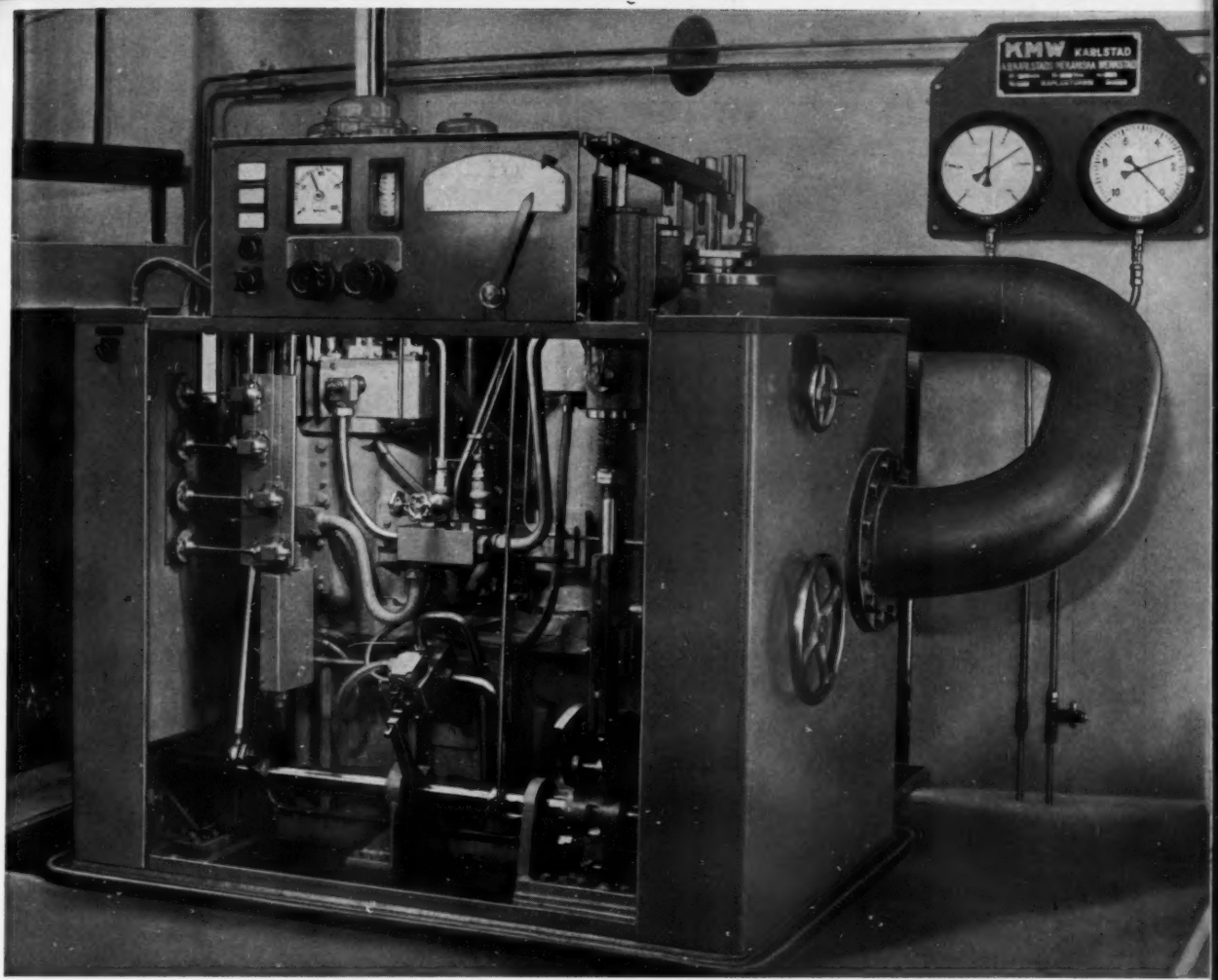
Above:
A 48kW induction generator driven by a 71 horsepower GILKES Francis turbine. This unit is installed in the Lochay Fish Pass, part of the North of Scotland Hydro-Electric Board's Breadalbane Scheme.

GILBERT GILKES & GORDON LTD

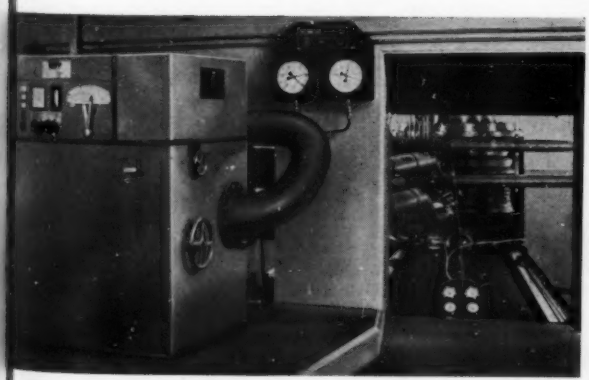
WATER TURBINE & PUMP MANUFACTURERS

KENDAL Telephone: Kendal 28 **ENGLAND**

London Office: CRAVEN HOUSE, KINGSWAY, LONDON W.C.2 Telephone: HOLBORN 3231



New design
OF GOVERNORS



At Järkvissle power station, belonging to the Swedish State Power Board, two KMW Kaplan turbines, each having a nominal rating of 59,500 hp at 13.6 m (45 ft.) head and 75 r.p.m., are now in service.

The station is equipped with electrical governors. The actuator, the control valves for gate and runner servomotors, and the combinator gear are grouped in a closed cabinet, placed near the turbine pit.

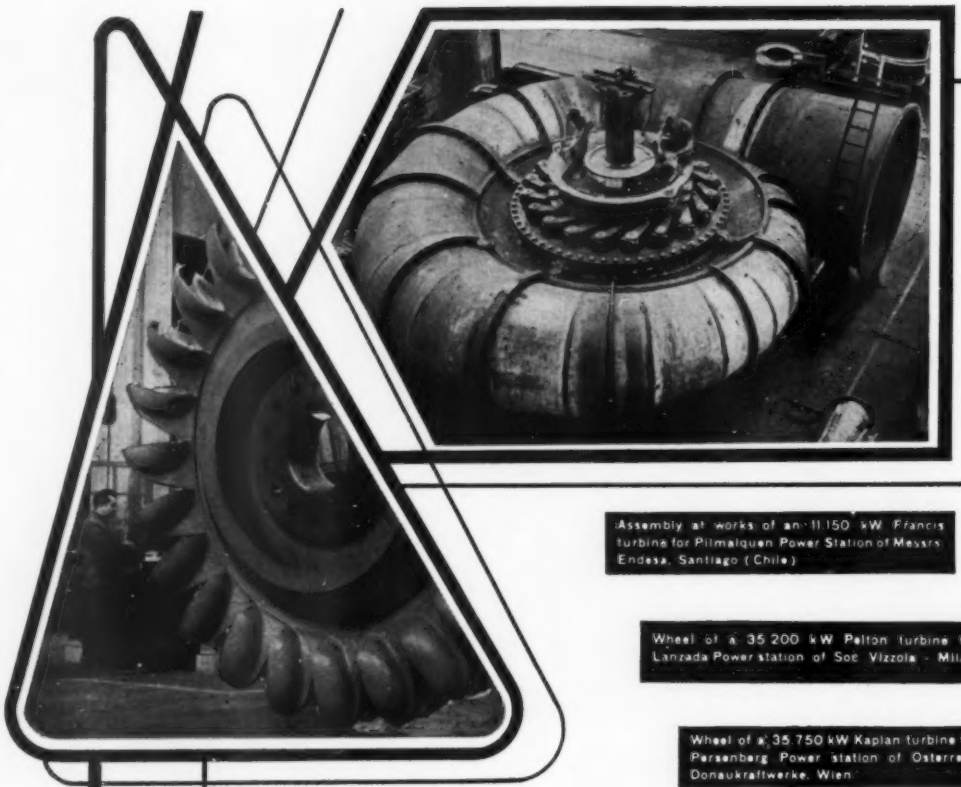
Oil is brought to the runner servomotor through a pressure oil box on the turbine shaft. The servomotor restoring gear is electro-hydraulic and arranged in the generator.

AB KARLSTADS MEKANISKA WERKSTAD
KARLSTAD SWEDEN

Representatives in Canada: A. Johnson & Co. (Canada) Ltd.
607 Shell Tower Building, Montreal 2

KMW

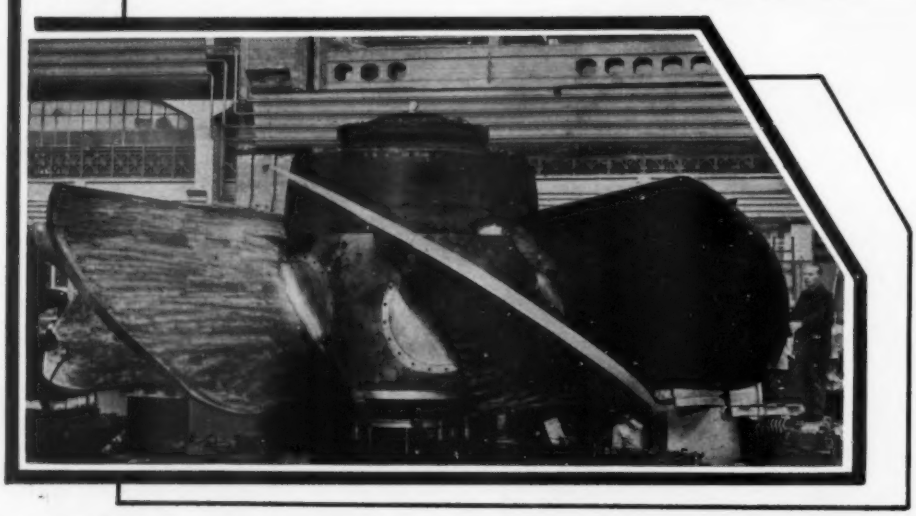
Complete hydro-electric plants



Assembly at works of an 11 150 kW Francis turbine for Pilmaiquen Power Station of Messrs. Endesa, Santiago (Chile)

Wheel of a 35 200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35 750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.

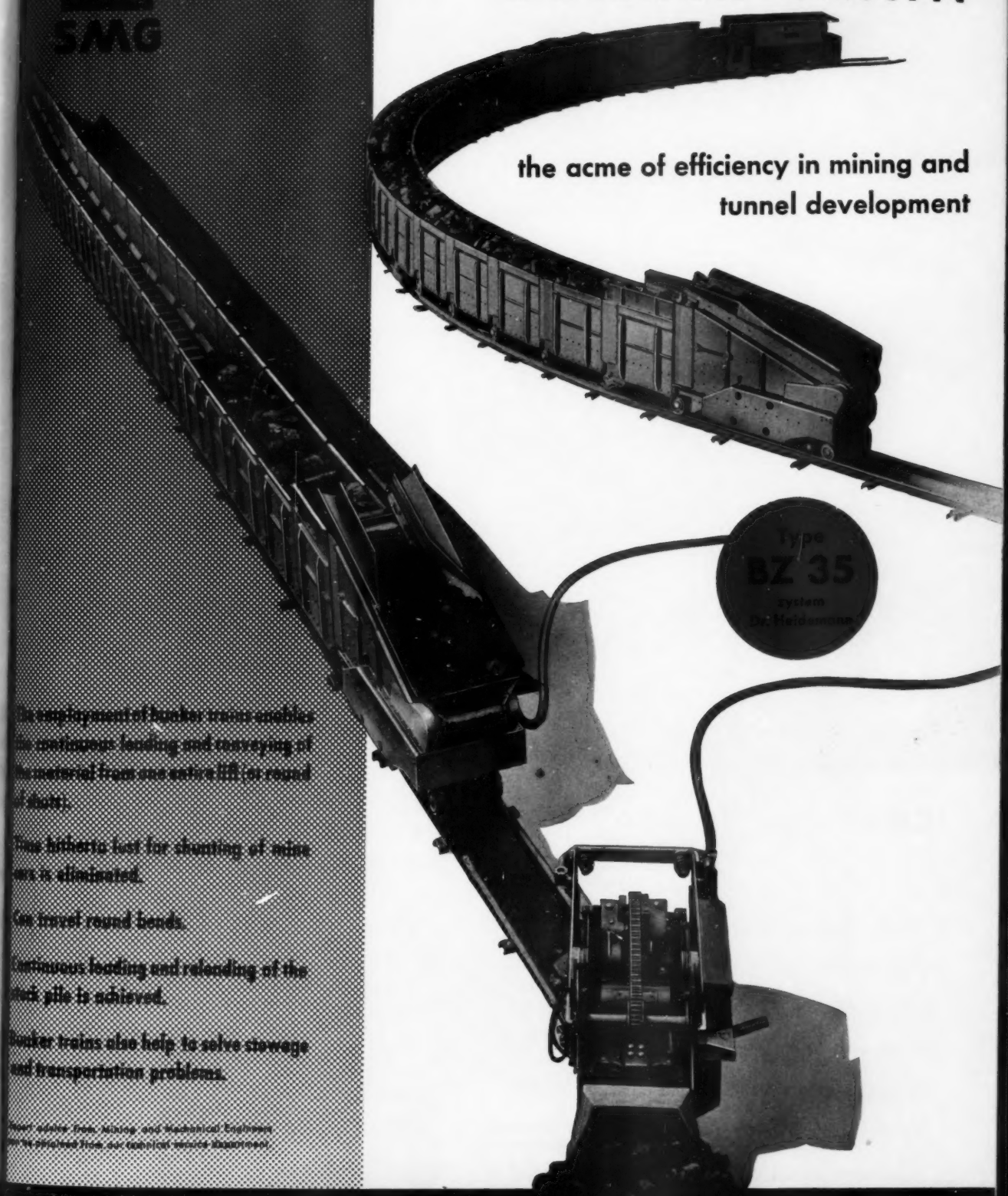


ANSALDO-SAN GIORGIO
GENOVA

SMG

SALZGITTER
BUNKER TRAIN

the acme of efficiency in mining and tunnel development



The employment of bunker trains enables the continuous loading and conveying of the material from one entire lift (or round of shots).

Time hitherto lost for shunting of mine cars is eliminated.

No travel round bends.

Continuous loading and reloading of the work pile is achieved.

Bunker trains also help to solve stowage and transportation problems.

Please address from Mining and Mechanical Engineers are supplied from our technical service department.

SALZGITTER MASCHINEN AKTIENGESELLSCHAFT

SALZGITTER-BAD

phone [illegible] F.R. of Germany [illegible]

CONTINUOUS STAVE WOOD PIPE:
a new publication now available

Built with ease over difficult terrain, treated wood stave pipelines are unique among all the methods and materials in use today. Component parts can be delivered to inaccessible sites and assembled on the grade by local labour without difficulty, in spite of complex curvatures.

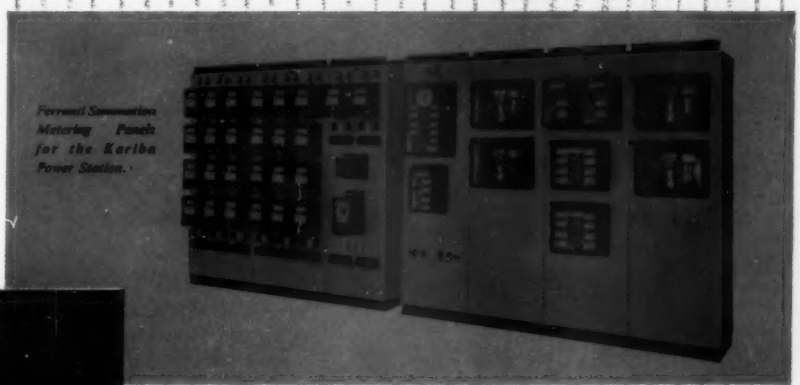
Engineers should be familiar with the economy and many advantages of this pipe for high-line conduits, penstocks and irrigation projects. Our recent publication: *CONTINUOUS STAVE WOOD PIPE*, reveals details of history, uses, construction and maintenance, together with design data and flow tables. Write for your copy.

CANADIAN WOOD PIPE & TANKS LIMITED

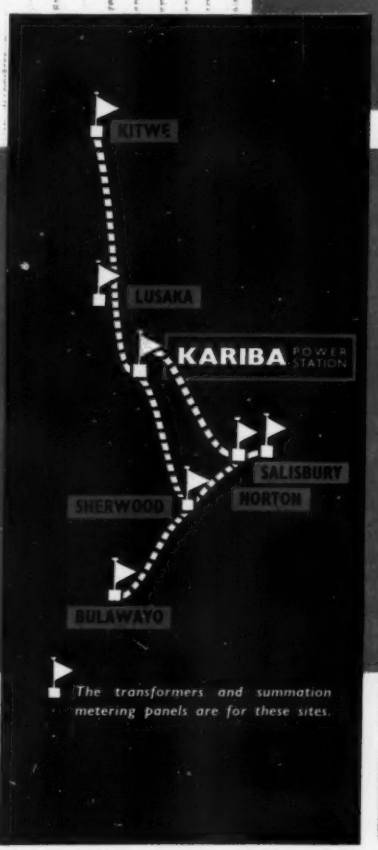
550 Pacific Street,
Vancouver 2, British Columbia,
Canada

One of the two Ferranti 120,000 kVA 330/234 kV auto transformer and series booster installations at the Kitwe sub-station.

FERRANTI at KARIBA



Ferranti Summation Metering Panels for the Kariba Power Station.



The transformers and summation metering panels are for these sites.

TRANSFORMERS

All the sub-station transformers for the Kariba Hydro-Electric Scheme are being supplied by Ferranti Ltd. They comprise two 120,000 kVA, 330/234 kV 3-phase auto transformers with series boosters, eight 60,000 kVA, 330/88kV and four 60,000 kVA, 330/33 kV 3-phase double wound transformers. The transformer installations at Norton, Lusaka and Kitwe are complete. Work at Salisbury, Bulawayo and Sherwood is well advanced.

SUMMATION METERING

For the same scheme Ferranti Ltd. are supplying Summation Metering Equipment comprising: Precision grade integrating meters, Electro-mechanical summators, Printometer Demand Recorders and Suites of metering cubicles. These equipments will be used to meter six 100 MW generator sets at Kariba Power Station and also the supplies to the Transforming Stations at Kitwe, Norton, Salisbury, Lusaka, Sherwood and Bulawayo.

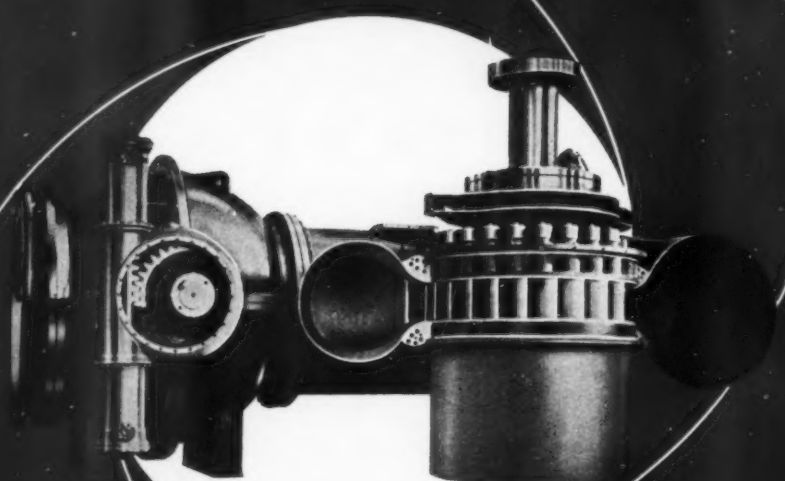
The consulting electrical and mechanical engineers are Messrs. Merz & McLellan.

FERRANTI LTD · HOLLINWOOD · LANCS · Tel: FAIlsworth 2000
London Office: KERN HOUSE · 36 KINGSWAY · W.C.2 · Tel: TEMple Bar 6666

Ferranti

FG 307/2

COMPLETE EQUIPMENT
FOR WATER POWER PLANTS

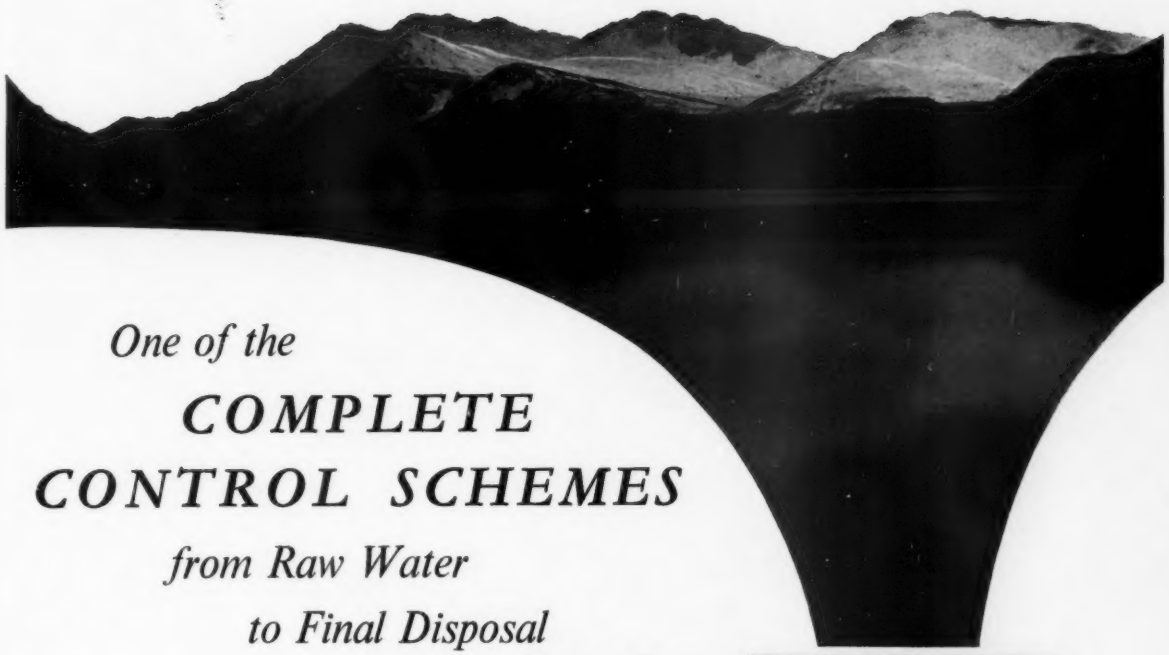


Turbines of the Francis, Kaplan and Pelton type for various heads and outputs, transformers, generators, outdoor and indoor switch-gear, control rooms, etc.

The well-known ŠKODA and ČKD trade-marks guarantee the first-class technical design and quality of equipment supplied by us. We give financial guarantees for complete deliveries.

TECHNOEXPORT

Foreign Trade Corporation for Export of Complete Industrial Plants
14, Václavské náměstí, Praha II.,
CZECHOSLOVAKIA

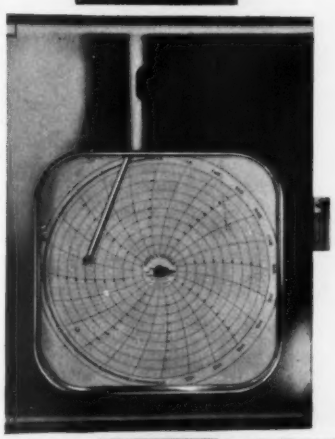


One of the

COMPLETE CONTROL SCHEMES

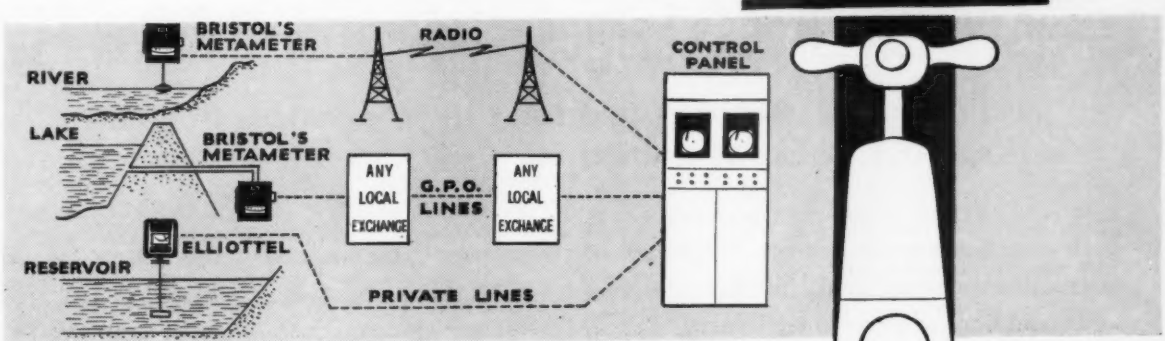
from Raw Water to Final Disposal

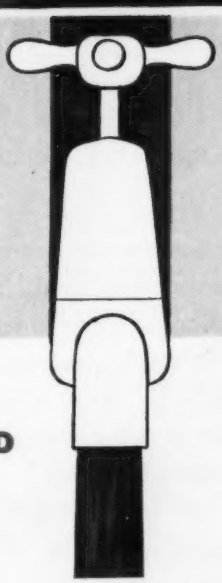
BY ELLIOTT



Heavy Loads on today's Water Schemes

The constantly increasing domestic needs and expanded industrial demands for water, have pushed the load on most water systems up close to their maximum capacities. *Operations at or near capacity make accurate, continuous measurement of water pressure, level and flow of the utmost importance.* As demands for water vary with the hour of the day, day of the week, and season of the year, pressures at the consumer's outlets will vary correspondingly unless they are constantly measured and effectively controlled.





Process Control Division
Water Industries Section

ELLIOTT BROTHERS (LONDON) LIMITED

Century Works, Lewisham, London S.E.13 Tel: TIDeway 1271

member of the Elliott-Automation Group

Original site of Aldeadavila with overlay of hydro system

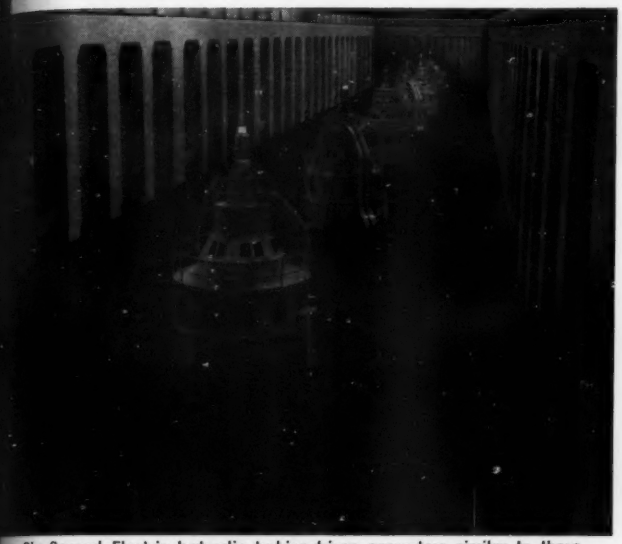
Iberduero S. A. Turns To General Electric To Equip Aldeadavila...Europe's Largest Underground Power Plant

Aldeadavila, scheduled for full operation in 1962, will have a total installed capacity of 756,000 KVA.

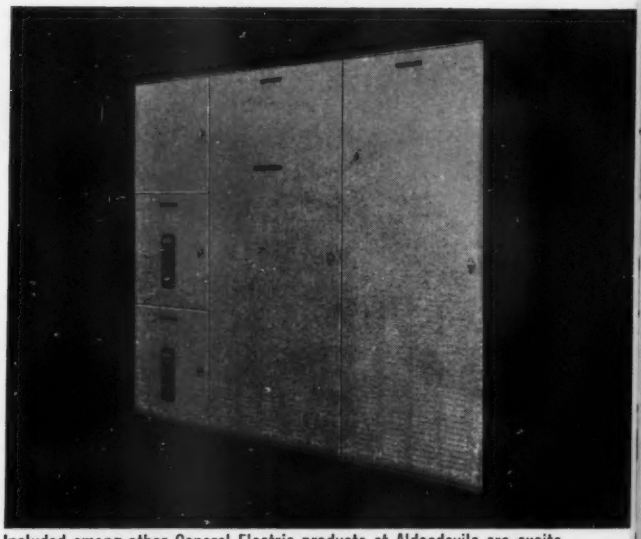
The Aldeadavila Hydroelectric project was born out of one of history's fine examples of international co-operation. In 1927, Portugal and Spain signed an agreement to participate in full utilization of hydroelectric potential of the Duero River. In 1935, Spain's largest utility started their country's program with Esla, the first hydroelectric station in operation on the Duero. Upon completion of Aldeadavila, the full utilization of the Spanish section of the river will be realized.

General Electric is playing a major role in supplying the necessary equipment for this great station. Six G-E 126,000 KVA hydraulic-turbine driven generators will help produce 2-million kilowatt hours per year. This will increase Iberduero's total capacity by some 65%. In addition to other General Electric products, the station will be equipped with G.E.'s new automated load dispatching equipment which will increase dependability and cut operating costs.

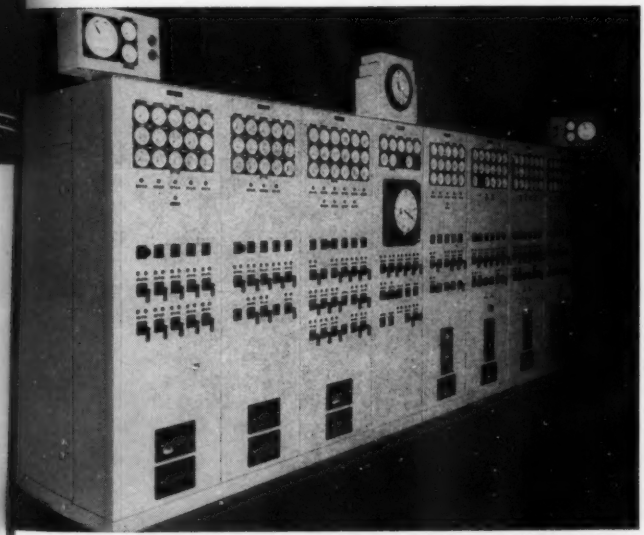
Six Dependable G-E Generators and Other Auxiliary Equipment Will Combine To Produce 2 Million Kilowatts Per Year



Six General Electric hydraulic turbine-driven generators similar to these will be installed and operating at Aldeadavila by 1962. These units will be rated at 126,000 KVA, 0.95 p.f.; 187.5 r.p.m., 13,800 volt 3-phase 50 cycle, and will be equipped with G-E thrust bearings.



Included among other General Electric products at Aldeadavila are excitation and regulator equipment. This indoor field excitation unit, shown here with the doors closed, houses field switch, voltage regulator and rheostat. G-E also manufactures reliable outdoor field excitation equipment.



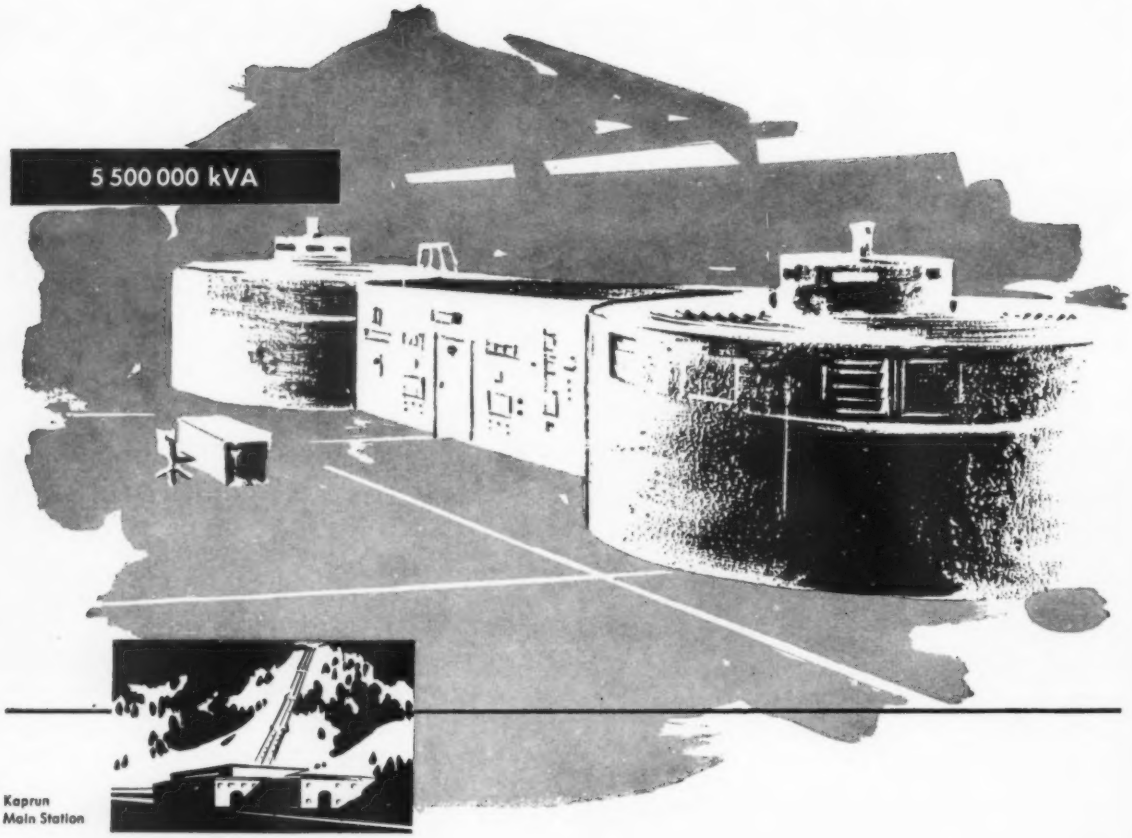
G-E Duplex Control Switchboards control power generation and distribution. Known as the "Tunnel Type Duplex", it features a walk-through design with doors at both ends to permit access to the interior for easier maintenance and test operations.

Iberduero, S.A. has ordered six generator control desks similar to this for Aldeadavila. This model includes control switches, indicating lamps, indicating instruments and mimic bus. G.E.'s full line of control desks is particularly applicable to continuous process control functions.

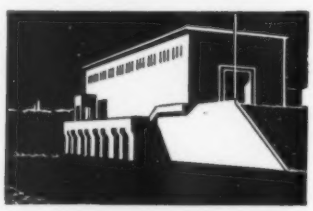
Whether it's hydroelectric or thermal power, the General Electric equipment installed in principal plants all over the world reflects G.E.'s outstanding performance and long experience in the electric utility field. For information on how General Electric can assist you, contact your nearest G-E representative or write: *International General Electric Co., Dept. 10-12, 150 East 42nd St., New York 17, New York, U.S.A.*

GENERAL ELECTRIC

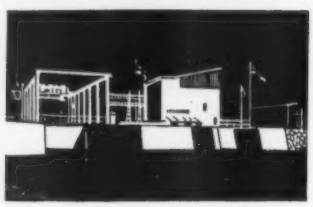
—U.S.A.—



Kaprun
Main Station



Seriyar
Hydro-Electric
Power Station



Pamila
Hydro-Electric
Power Station

5 500 000 kVA
is the aggregate rating of water wheel generators AEG so far supplied or for which contracts have been placed.

Since the beginning of 1946 alone contracts for the supply of water wheel generators from smallest ratings up to 100000 kVA units totalling over 2000000 kVA have been placed with our organization.

During the past 60 years AEG have built plants for generation, transmission and distribution of electrical energy obtained from hydro-electric stations and billions of kWh are made available anually by AEG water wheel generators.

AEG

Hydro-Electric Stations

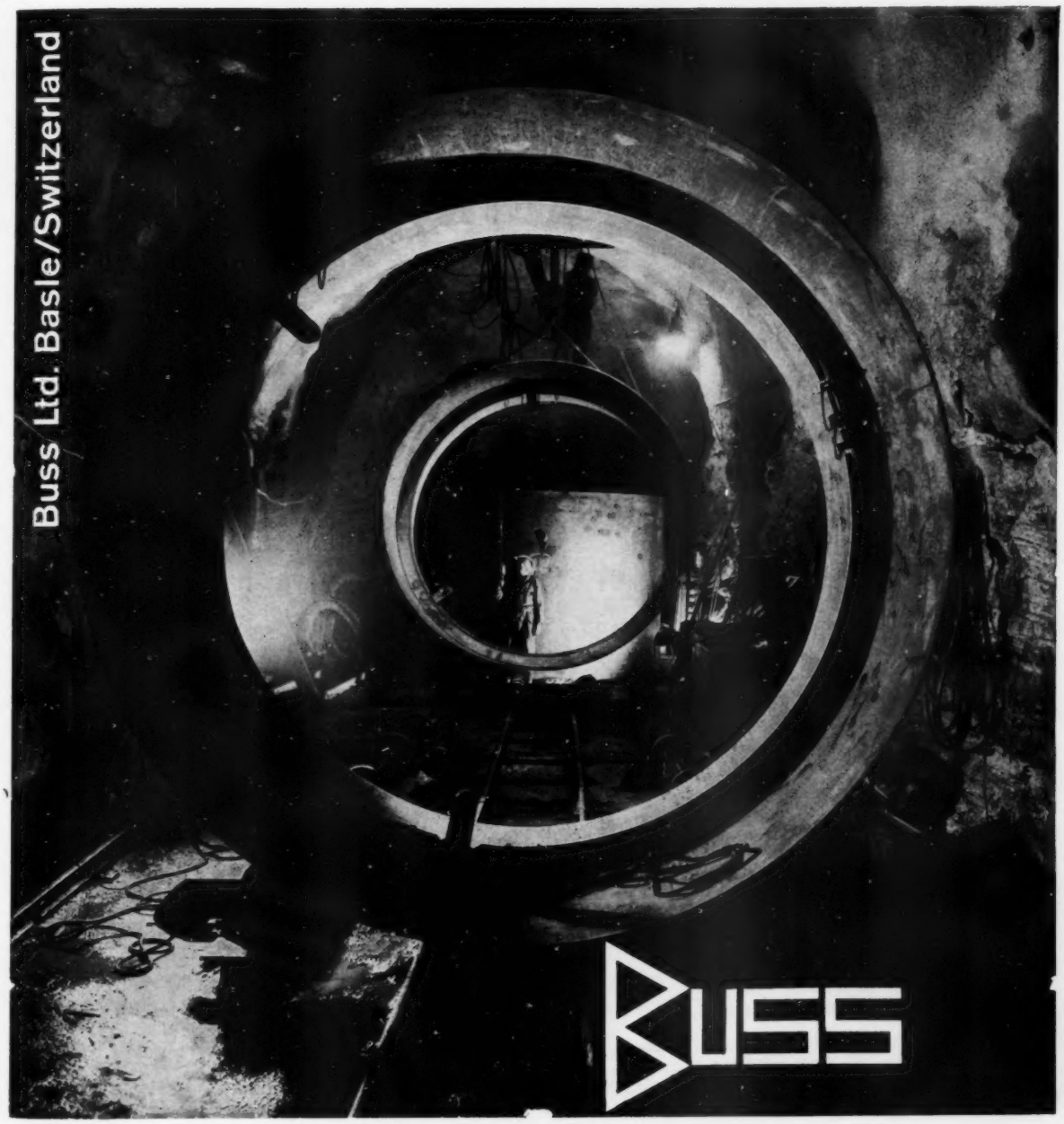
7914 e

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

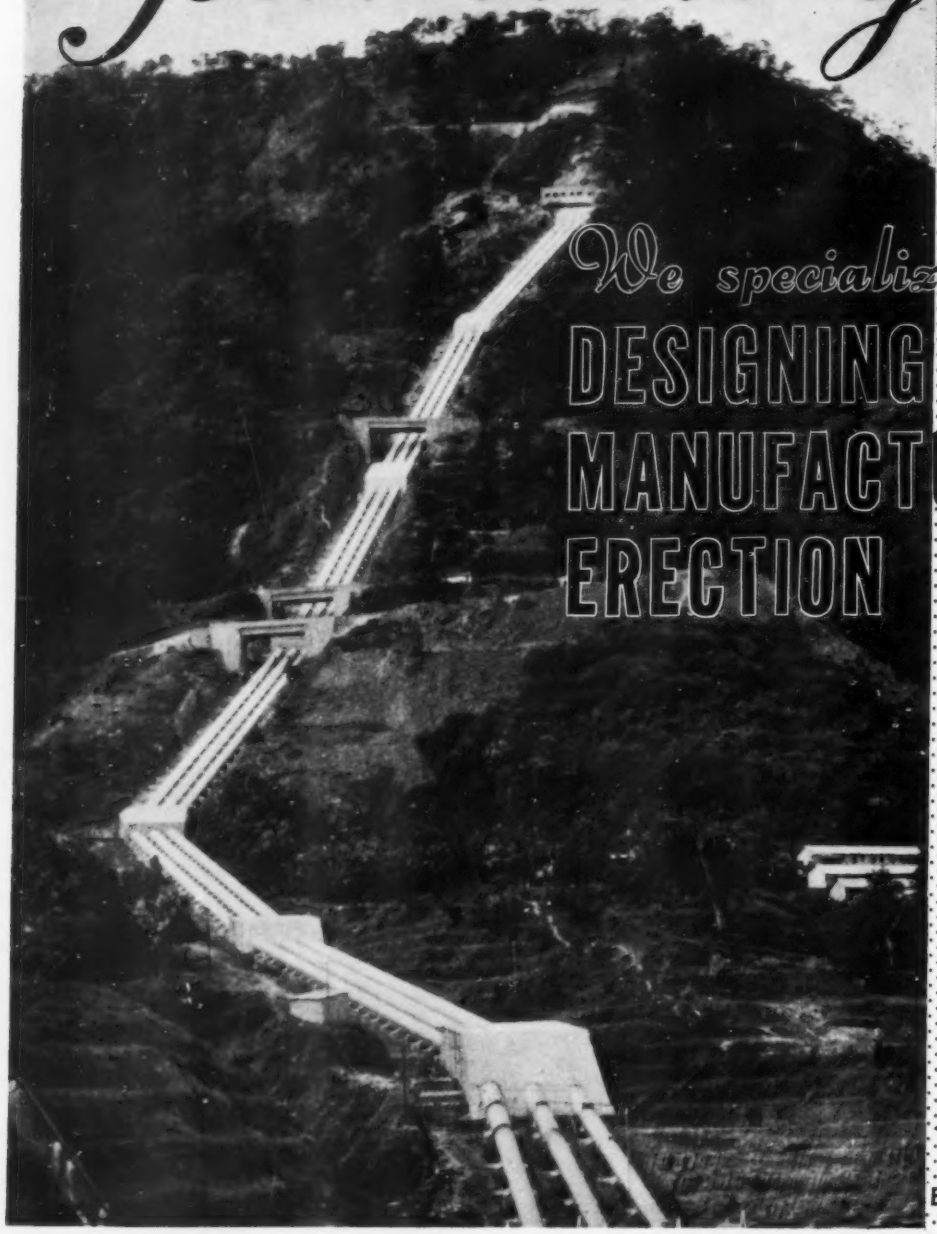
Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)

specialized

in penstocks and pressure shaft linings as well as in other equipment for hydro-electric power plants



Penstock and Gate



We specialize in . . .

DESIGNING
MANUFACTURING
ERECTION

Established: 1904

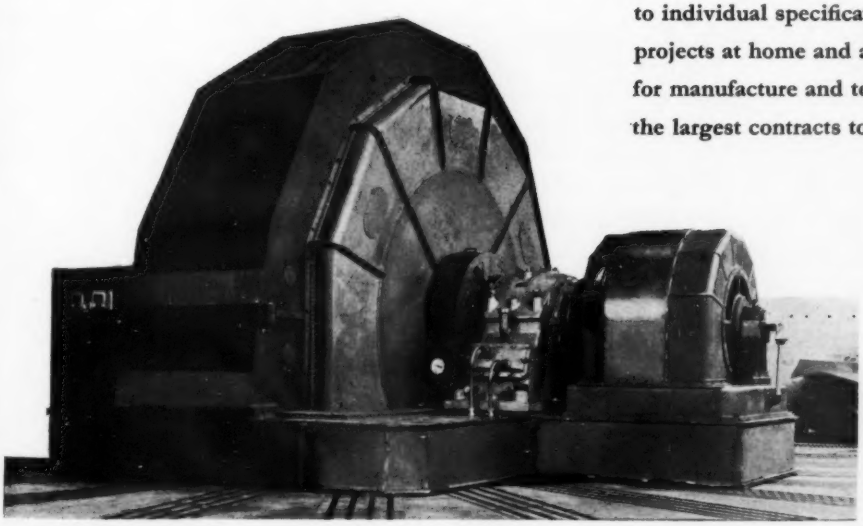
SAKAI IRON WORKS CO., LTD.

HEAD OFFICE: NISHI, 6-CHOME, TSUMORI-CHO, NISHINARI-KU, OSAKA, JAPAN CABLE ADDRESS: "SAKATETSU OSAKA"
TOKYO OFFICE: NIHONBASHI-GOFUKUBASHI, CHUO-KU, TOKYO, JAPAN CABLE ADDRESS: "SAKATETSU TOKYO"

Hydro-Electric Generators

Rotor for a 3,500 kW 3.3 kV 167 r.p.m. vertical generator for the Lairg power station of the North of Scotland Hydro-Electric Board.

Bruce Peebles build generators, large or small, horizontal or vertical, designed to individual specifications, for hydro-electric projects at home and abroad. Ample resources for manufacture and testing enable the largest contracts to be undertaken.



One of two 12 MW 11 kV 375 r.p.m. horizontal generators for the Shin power station of the North of Scotland Hydro-Electric Board erected for test.

BRUCE PEEBLES & Co Limited ENGINEERS EDINBURGH

AEI ELECTRICAL EQUIPMENT

For the World's largest pumped storage scheme

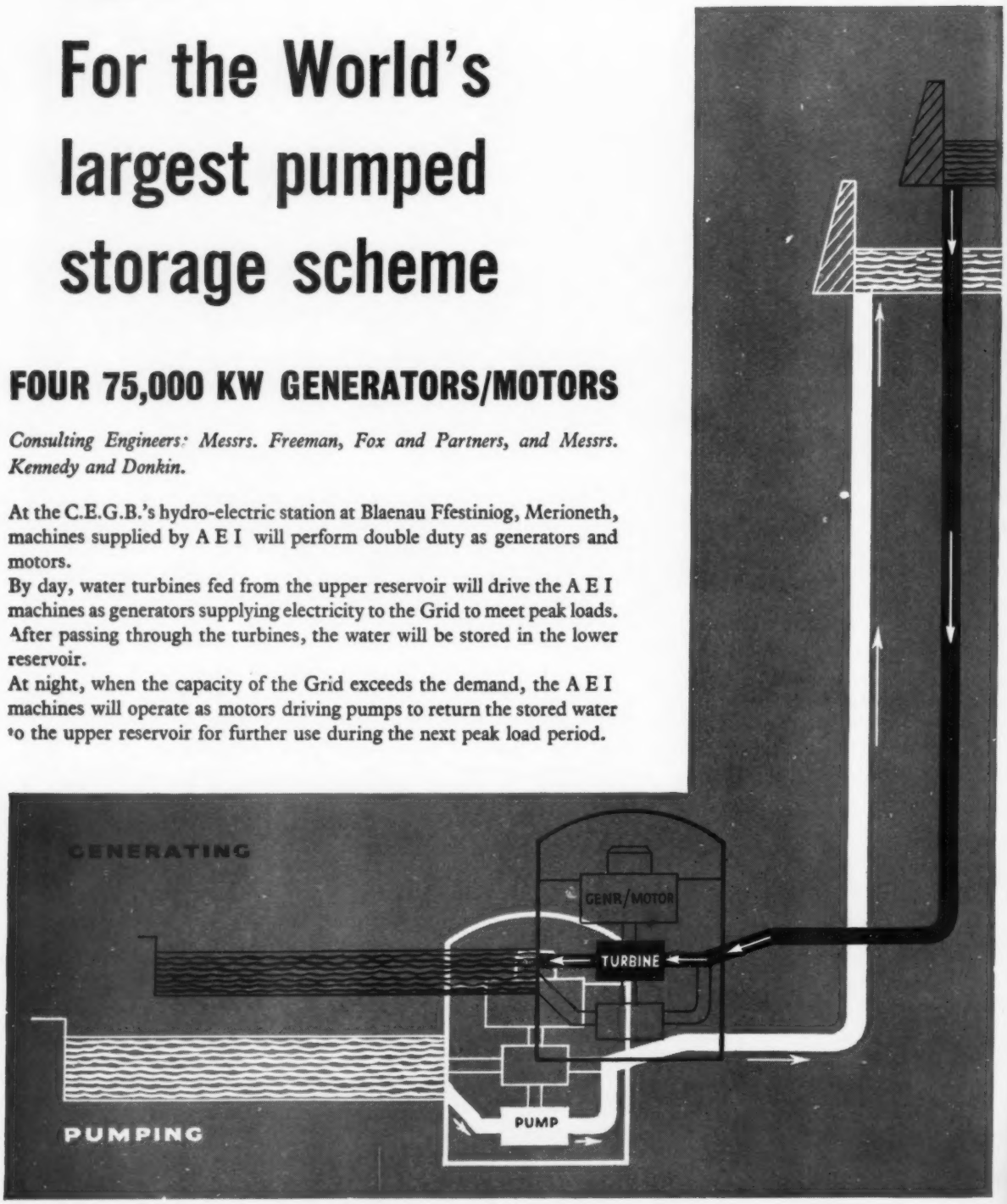
FOUR 75,000 KW GENERATORS/MOTORS

Consulting Engineers: Messrs. Freeman, Fox and Partners, and Messrs. Kennedy and Donkin.

At the C.E.G.B.'s hydro-electric station at Blaenau Ffestiniog, Merioneth, machines supplied by A E I will perform double duty as generators and motors.

By day, water turbines fed from the upper reservoir will drive the A E I machines as generators supplying electricity to the Grid to meet peak loads. After passing through the turbines, the water will be stored in the lower reservoir.

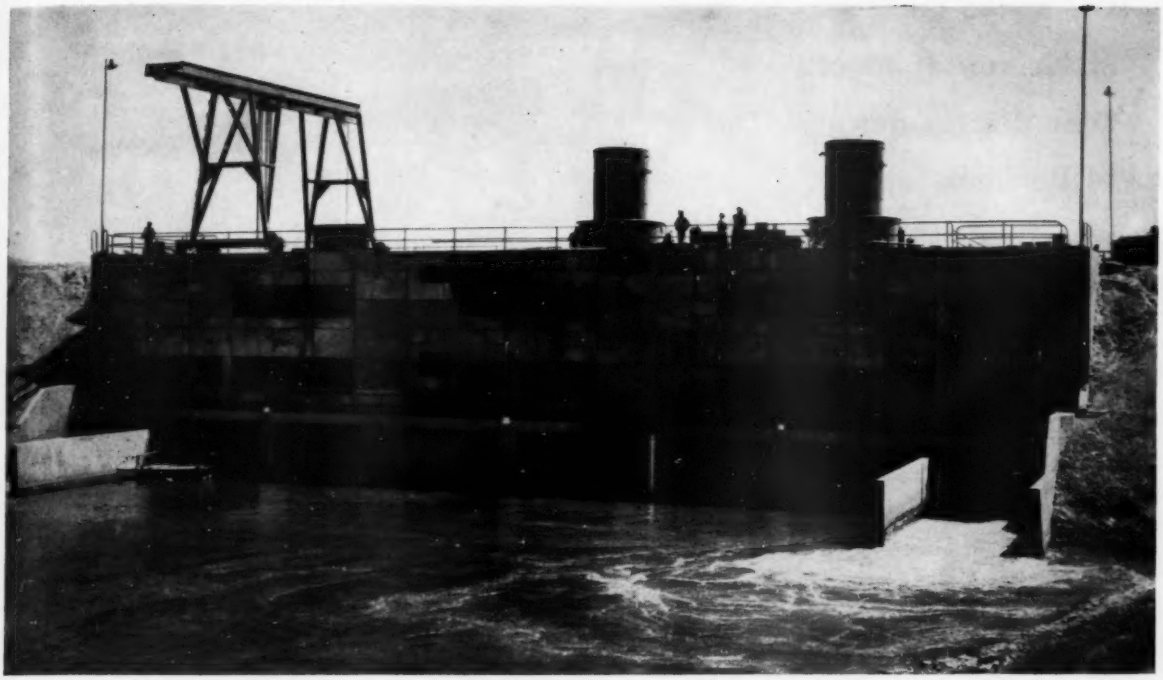
At night, when the capacity of the Grid exceeds the demand, the A E I machines will operate as motors driving pumps to return the stored water to the upper reservoir for further use during the next peak load period.



ASSOCIATED ELECTRICAL INDUSTRIES LIMITED

HEAVY PLANT DIVISION — RUGBY AND MANCHESTER, ENGLAND

A5387



2 Leffel Turbines Help Provide Power for Peace at the Girishk Power Development in Afghanistan

Close up of Generator Unit #2 at Girishk, showing two Afghan employees of Morrison-Knudsen Afghanistan, Inc. in native dress. Photo at top of page shows downstream side of Girishk Power Plant. Mechanical gallery is on lower deck, electrical gallery on upper deck.

Typical of the job being done by Leffel turbines in all parts of the world — wherever efficient development of water power resources can contribute to peace and prosperity — is the Girishk Power Plant in southwestern Afghanistan.

This plant was designed by International Engineering Company, Inc., and built by Morrison-Knudsen Afghanistan, Inc. for the Helmand Valley Authority, an agency of the Royal Government of Afghanistan. Designed for three 1500 KW generators, the plant was completed in June, 1958 with two generators installed, each driven by a Leffel vertical shaft turbine developing 2200 H.P. at 187.5 R.P.M. with a net head of 25 feet.

Thousands of installations such as this one have helped build Leffel's reputation for high efficiency, long life and reliable service. And every Leffel turbine is backed by more than nearly a century of experience. That experience is available to you, without obligation, whether your project is a new installation or the expansion or rehabilitation of existing facilities. Just write, outlining your requirements.

1113-E

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

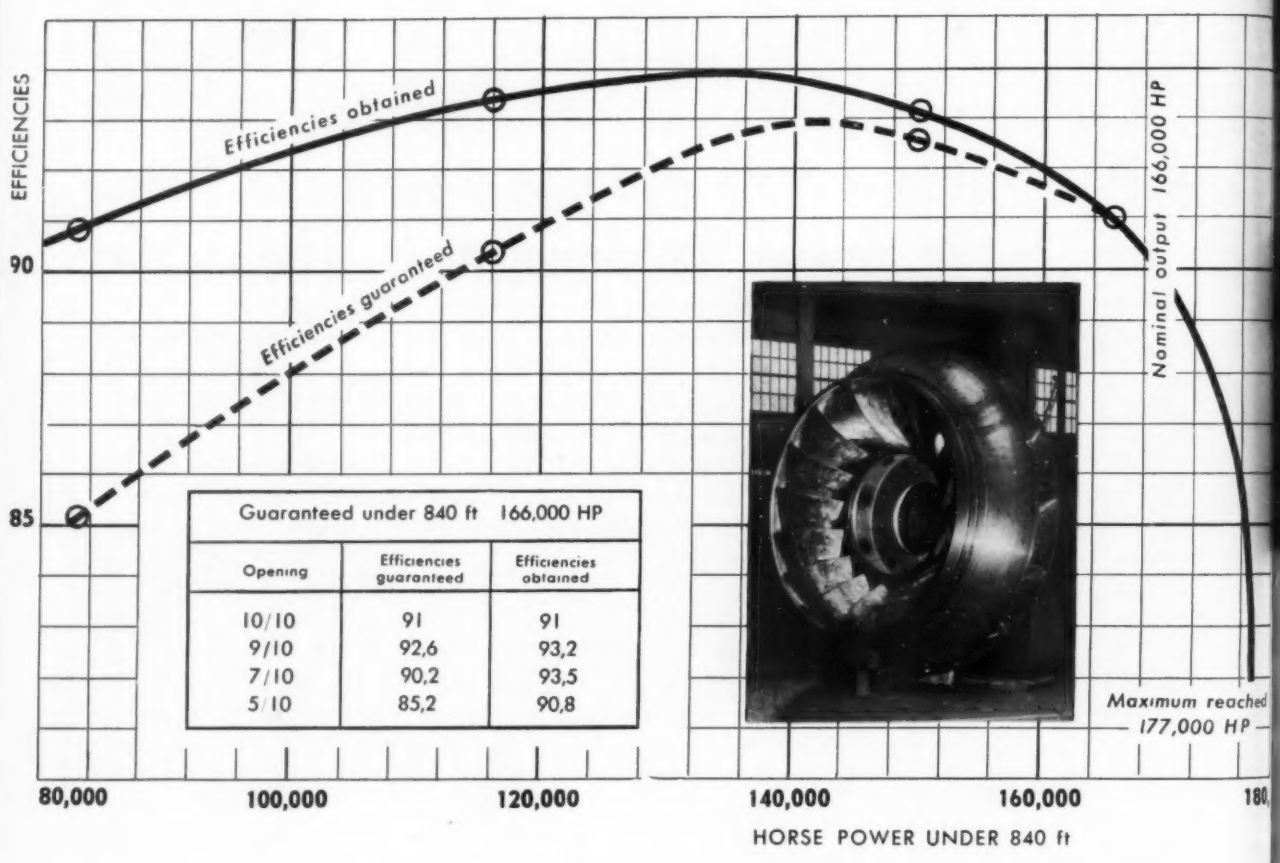
DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 98 YEARS

The sound qualities of Neyrpic turbines were again confirmed at Bersimis when the efficiencies of units 5 to 8 exceeded the guaranteed values

BERSIMIS
CANADA

Bersimis Neyrpic turbines exceed expectations !



Guaranteed under 840 ft 166,000 HP		
Opening	Efficiencies guaranteed	Efficiencies obtained
10/10	91	91
9/10	92,6	93,2
7/10	90,2	93,5
5/10	85,2	90,8

GRENOBLE
Avenue de Beauvert
Téléphone : 44-55-30

NEYRPIC

PARIS XVI
2-10, Rue Bellini
Téléphone : PAS. 51-09

UNIFORMITY STRENGTH DURABILITY

NGK *Insulators*

Oriental porcelain has a history of several thousand years. Strong porcelain is nothing new to NGK who has long ago perfected its outstanding developments in the field of high voltage insulators through a background of over 40 years.

Suitably designed hardwares and experienced assembling techniques combine to constitute an integral basis on which NGK embodys its unsurpassed features of uniformity and durability.

You get so much more out of NGK Insulators.

Nippon Gaishi Kaisha LTD.

Cable: INSULATOR Nagoya. TELEX: NGK-NG9928
Represented in all major territories

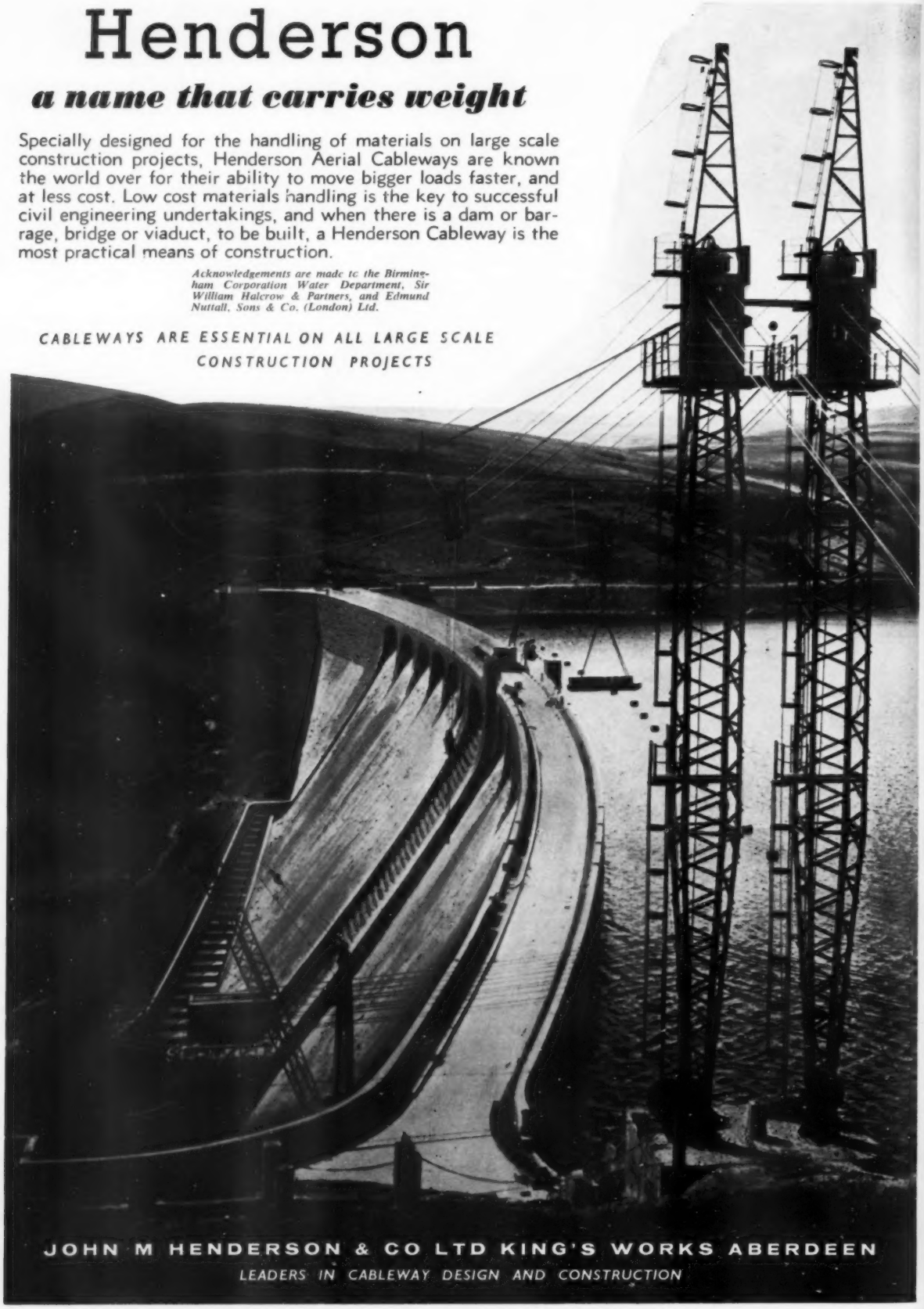
Henderson

a name that carries weight

Specially designed for the handling of materials on large scale construction projects, Henderson Aerial Cableways are known the world over for their ability to move bigger loads faster, and at less cost. Low cost materials handling is the key to successful civil engineering undertakings, and when there is a dam or barrage, bridge or viaduct, to be built, a Henderson Cableway is the most practical means of construction.

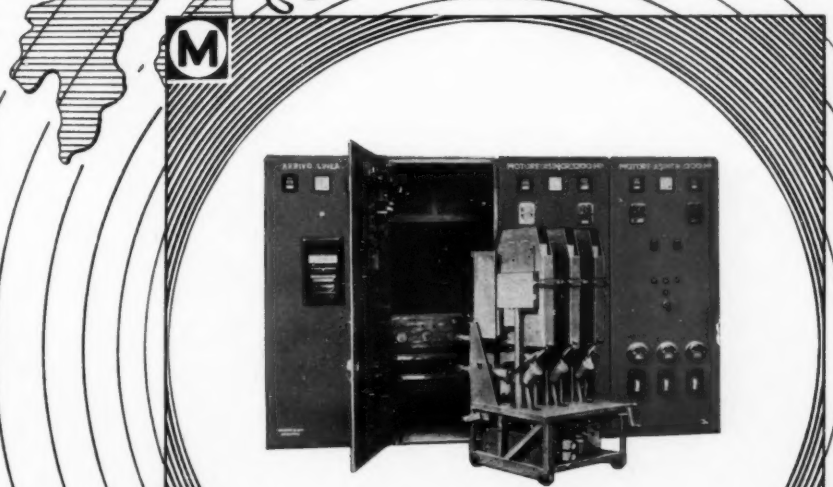
Acknowledgements are made to the Birmingham Corporation Water Department, Sir William Halcrow & Partners, and Edmund Nuttall, Sons & Co. (London) Ltd.

CABLEWAYS ARE ESSENTIAL ON ALL LARGE SCALE CONSTRUCTION PROJECTS



JOHN M HENDERSON & CO LTD KING'S WORKS ABERDEEN

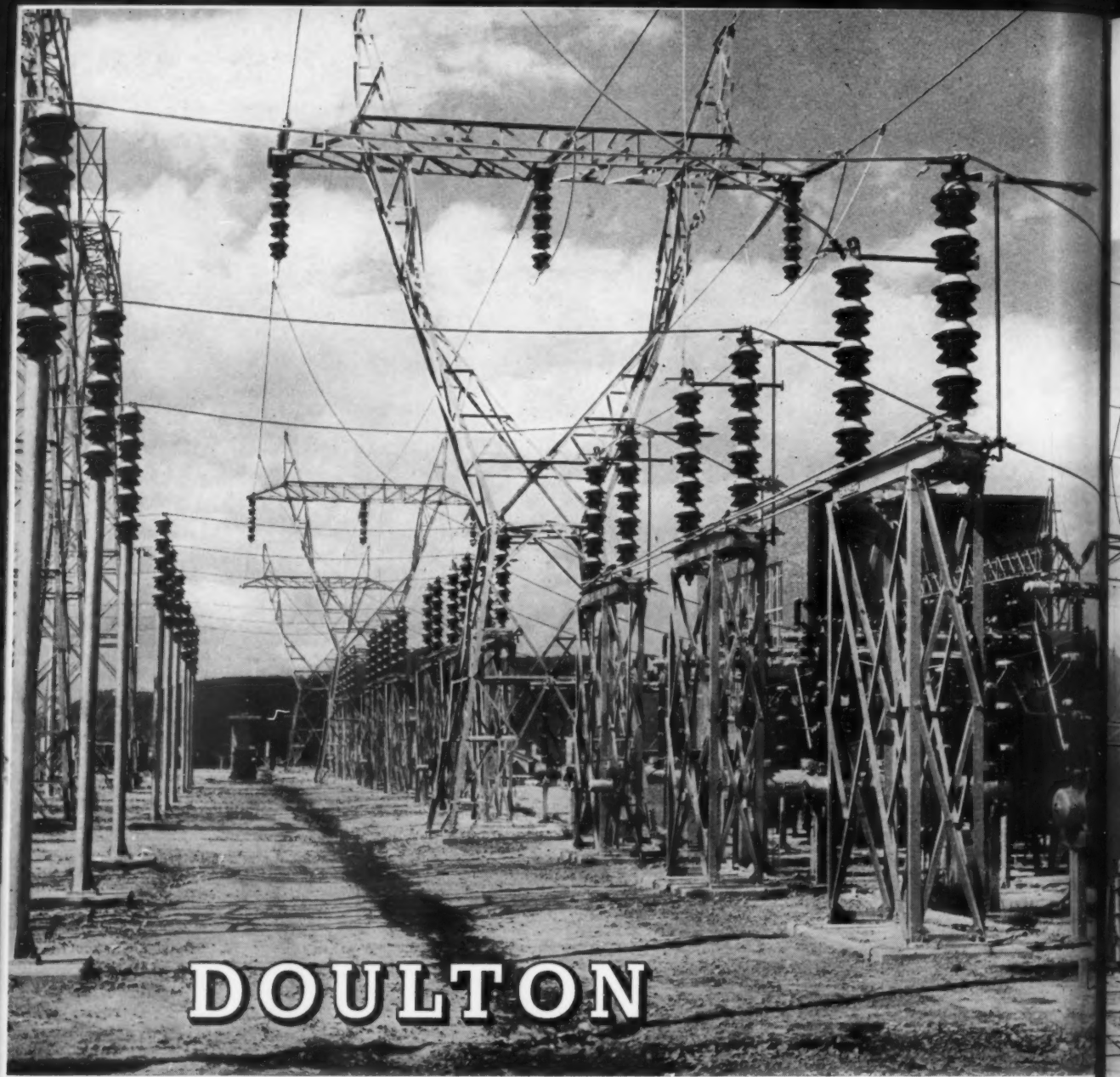
LEADERS IN CABLEWAY DESIGN AND CONSTRUCTION



Metal-clad switchgear for indoor operation
equipped with de-ion air circuit breaker
DH in the draw-out execution.

MAGRINI'S TRADE-MARK AND SWITCHGEAR WIN WORLD-WIDE RECOGNITION

MAGRINI S.P.A. - VIA L. MAGRINI 7 - BERGAMO - ITALY



INSULATORS

220 kV in Tasmania

Doulton BB 26 post insulators, for 220 kV working voltage, installed at the Chapel Street sub-station near Hobart of the Hydro Electric Commission of Tasmania. This station will eventually be enlarged to 560 MVA to supply the Hobart district.

DOULTON INDUSTRIAL PORCELAINS LIMITED
ROYAL DOULTON POTTERIES WILNECOTE · TAMWORTH · STAFFS.

Six single-phase transformers, cooled by separately mounted radiators, forming two 75 MVA three-phase banks, ratio 11 ± 5% / 260 kV. These transformers have been supplied to C.E.B. (Consorzio Elettrico del Buthier), Turin, Italy, for the Valpelline power station; and they have the highest voltage in the Aosta Valley power system.

società nazionale delle officine di

savigliano

Corso Mortara 4 - TORINO (ITALIA)

PENSTOCKS, PRESSURE SHAFT LININGS
FOR ALL WORKING PRESSURES

GIOVANOLA

Monthey-Switzerland

BUCYRUS-ERIE excavators are contributing towards progress by maintaining output and holding down costs on major projects

On public works construction as well as quarrying and mining, Bucyrus-Erie heavy-duty shovels and draglines are preferred. Illustrated is a 110-B 4½ cubic yard shovel, one of three employed on the Serre-Poncon earth dam project on the Durance river in Southern France. Two 150-B draglines were engaged on the same scheme. Over a hundred years have gone by since dam projects in this region were first visualised. Only the development of present-day technical resources has made the project possible—and the choice of excavators? Bucyrus-Erie.

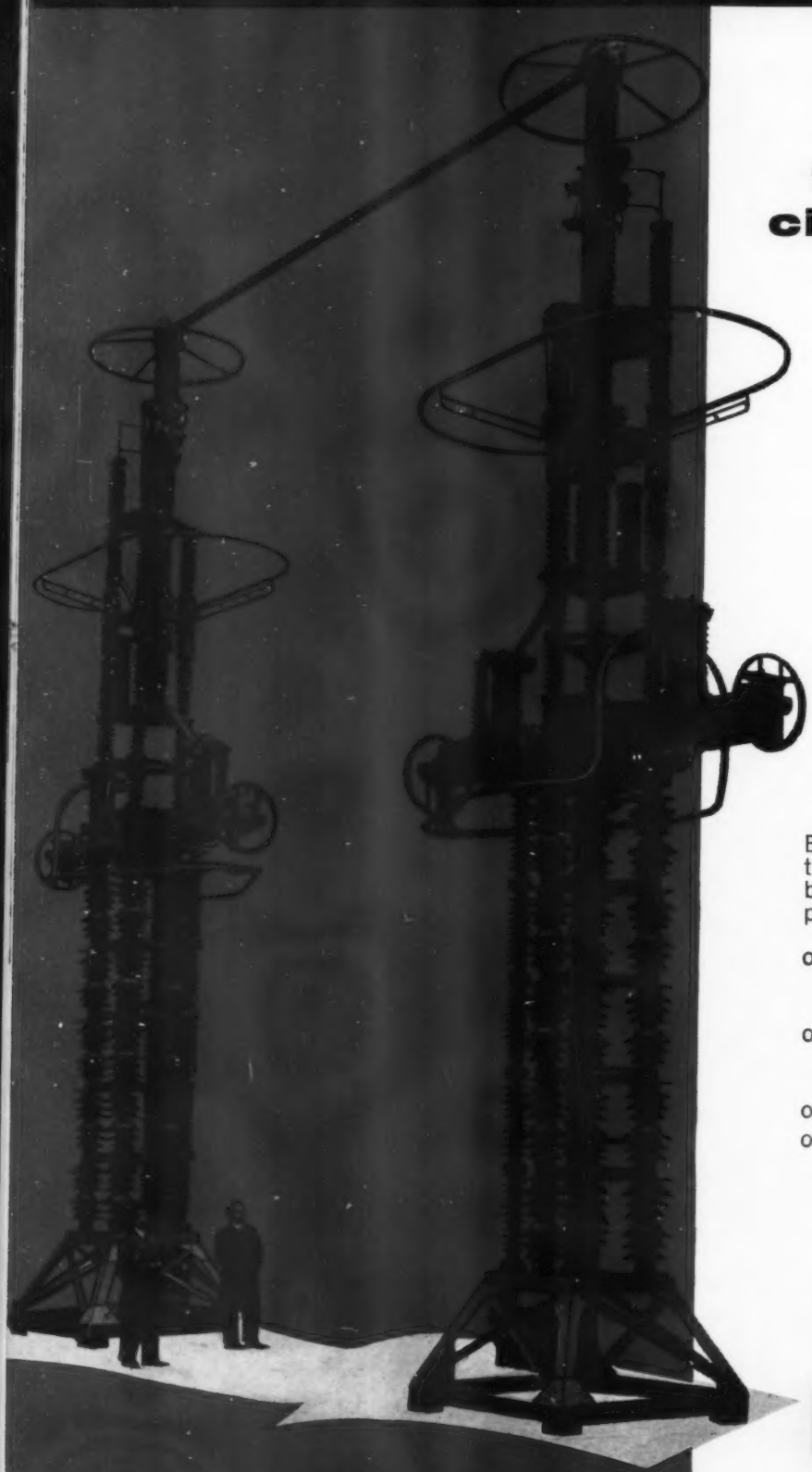
BUCYRUS ERIE

BUCYRUS-ERIE COMPANY

South Milwaukee, Wisconsin, U.S.A.

RUSTON-BUCYRUS LIMITED, LINCOLN, ENGLAND

FOR THE WORLD'S HIGHEST VOLTAGE TRA



One of the poles of a series of 525 kV, 25,000 MVA, AE 11 air blast circuit breakers, for the equipment of the U.R.S.S network.

the air blast circuit breaker

type AE

A range of breakers from 70 kV to 525 kV

Breaking capacity: 30,000 amp. rms.

Besides properties peculiar to the technique of air blast circuit breakers the type A E apparaters provides:

- o Breaking with high r.r.r.v. and ability to interrupt a kilometric fault.
- o Breaking of currents in unloaded power transformers with low overvoltages
- o Low air consumption.
- o Negligible burning of contacts.

Ateliers de Constructions Electriques de

Delle

25 CHEMIN DE CYPRIAN VILLEURBANNE (RHONE)

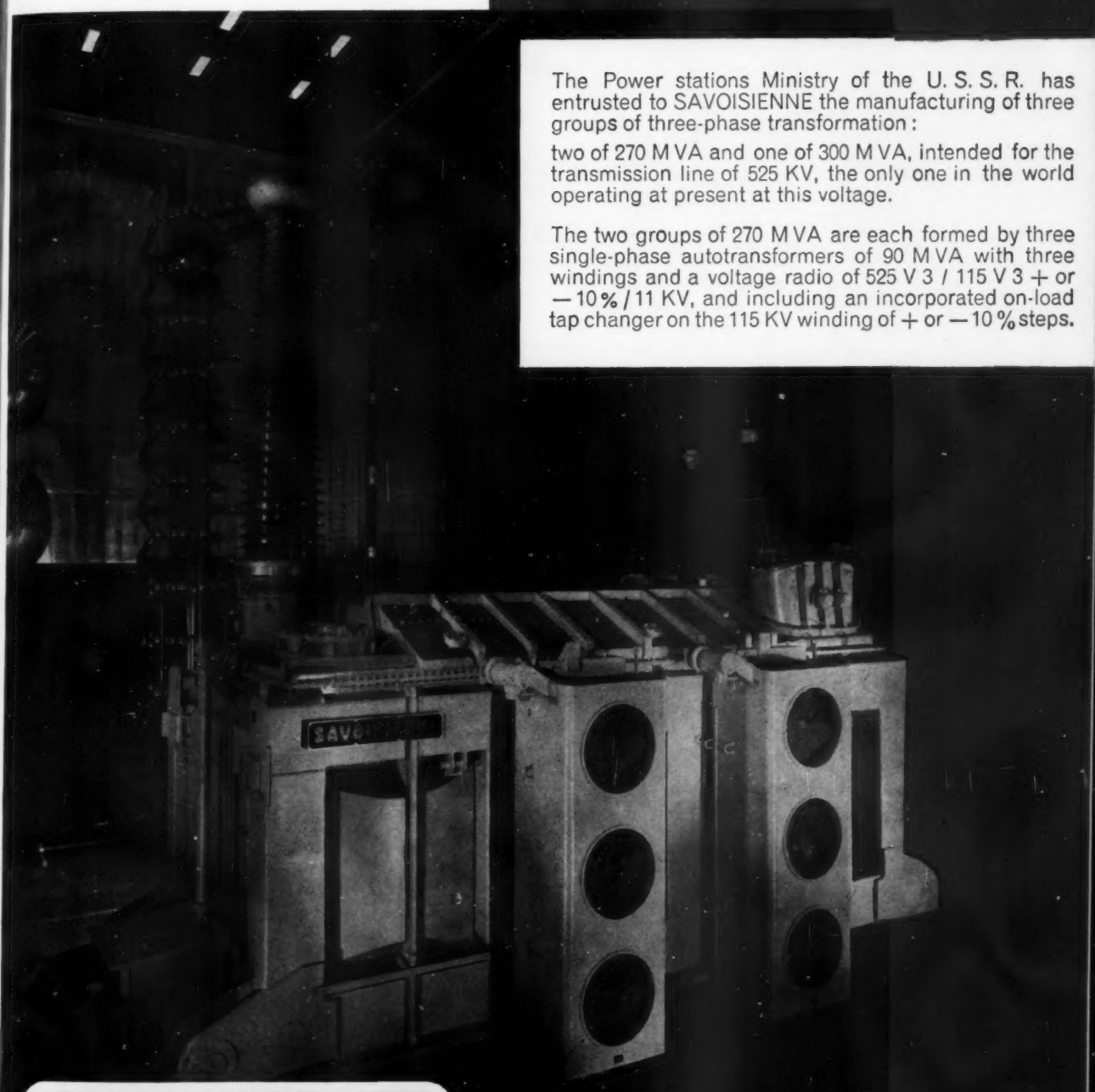
OF THE "COMPAGN GEN

TRANSMISSION LINE 525 KV

The Power stations Ministry of the U. S. S. R. has entrusted to SAVOISIENNE the manufacturing of three groups of three-phase transformation :

two of 270 MVA and one of 300 MVA, intended for the transmission line of 525 KV, the only one in the world operating at present at this voltage.

The two groups of 270 MVA are each formed by three single-phase autotransformers of 90 MVA with three windings and a voltage radio of 525 V 3 / 115 V 3 + or — 10 % / 11 KV, and including an incorporated on-load tap changer on the 115 KV winding of + or — 10 % steps.



The first transformer has successfully supported the final tests in the new SAVOISIENNE laboratory at Aix-les-Bains equipped with an impulse voltage generator of 175 Kilojoules whose maximum voltage reaches 4, 400, 000 volts.

SAVOISIENNE

AIX-LES-BAINS (Savoie)

GENERALE D'ELECTRICITE"

Speedy, easy, one-man control against full unbalanced pressure.

Simple operating mechanism — no separate protective devices.

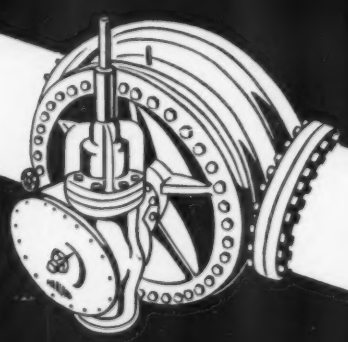
Minimum friction loss and no wear on valve seats.

Self-cleaning action between body and plug with no face-to-face friction.

Water-hammer controlled by positive valve timing and good design characteristics.

No underground chamber is required: the operating mechanism can be completely sealed.

Supplied in standard sizes from 12"-72" with electric motor, hydraulic or pneumatic servomotor or manual drives.



HARLAND-MORGAN SMITH

ROTOVALVES

THE HARLAND ENGINEERING COMPANY LIMITED ALLOA SCOTLAND

LONDON AND EXPORT SALES OFFICE: HARLAND HOUSE 20 PARK STREET W1

Branches in BRISTOL GLASGOW LEEDS NEWCASTLE NOTTINGHAM TIMPERLEY (CHESHIRE) WOLVERHAMPTON AND OVERSEAS

F 800/1

WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

Annually 40 shillings by post. Single Copies 2s. 6d.

Volume 12 Number 5

CONTENTS FOR MAY, 1960

Editorial: Meeting the Unexpected - - - 165

Editorial Notes - - - - - - 166

The Tumut I Project—I - - - - - 169
By B. K. Jaggar

The Water-Jet Pump—Its Uses in Hydro-Electric Schemes - - - - - - 176
By R. Silvester, B.A., B.E., Ph.D. (W.A.), A.M.I.E. (Aust.)

Designing Low-Cost Transmission Lines - - 181
By Lauri Haro and Pentti Haapanen

Underwater Blasting and Blasting Through Overburden —II - - - - - - - 189
By Ulf Langefors

Plans for the Drau - - - - - 198
By Dr. E. Königshofer

Short Articles: Spur Cable Racking System—New Bench Mounted Grinder—Allis-Chalmers HD.6G Tractor Shovel—New Expansion Jointing Development—New C.P. Wet Pick—St. Malo Tidal Plant in Service—The Sykes 12 in. Univac Pump - - - - 203

Abstracts from the World Technical Press - - 207

Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

PUBLISHED BY TOTHILL PRESS LIMITED

33 Tothill Street, Westminster, London, S.W.1

Telegrams: Trazette, Parl, London. Telephone: Whitehall 9233 (20 lines)

MANCHESTER: Century Insurance Building, St. Peter's Square. Telephone: Central 7667/8/9

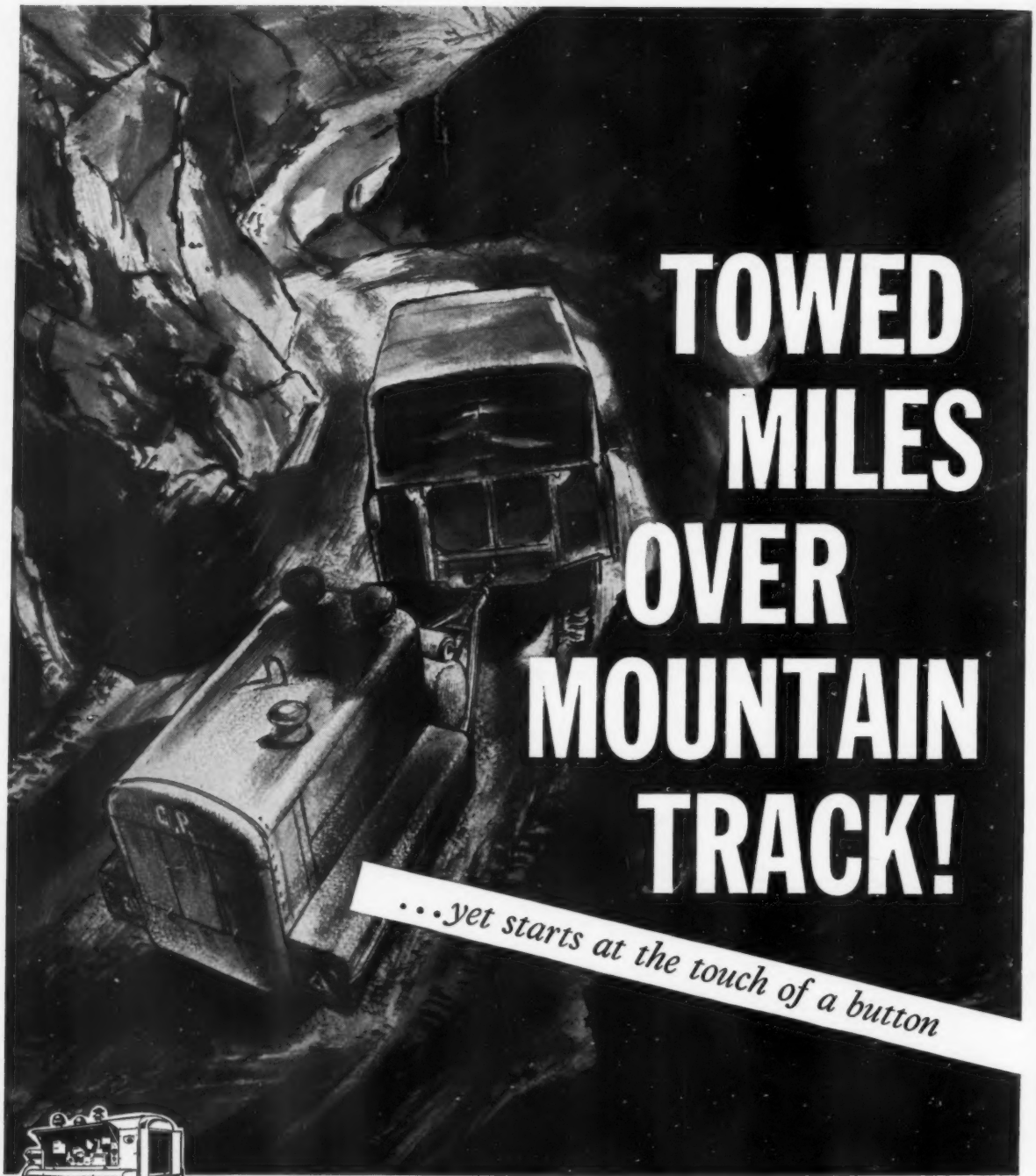
BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466

NEWCASTLE-ON-TYNE: 21 Mosley Street. Telephone: 22239

GLASGOW: 139 Bothwell Street. Telephone: Central 4646

LEEDS: 70 Albion Street. Telephone: 27174

BRISTOL: 20 Victoria Square, Clifton. Telephone: Bristol 33873



The toughness of "Power Vane" Rotary Compressors

A report from Scandinavia refers to one of the smallest CP "Power Vane" rotary compressors, the model 125-RO-2 working on road construction in difficult mountainous country. This machine has received some of the toughest treatment ever. Towed for miles over rough mountain track and later used as an auxiliary unit in the discharge tunnels of a dam and power station contract, this ruggedly built "Power Vane" compressor started up every time at the touch of a button.

Leading contractors throughout the world use "Power Vane" rotary compressors because of their reputation for toughness in all operating conditions.

Consolidated Pneumatic

CONSOLIDATED PNEUMATIC TOOL COMPANY LIMITED · DAWES ROAD · LONDON · S.W.6

CRANE CP/202

WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

Meeting the Unexpected

DURING the latter part of October, the citizens of the capital city of one of the world's leading water-power countries, Norway, were told that electricity would have to be turned off for two hours in every twenty-four, and they were earnestly exhorted to save electricity at all times. The city's trams were stopped at various times during the day. These unfortunate occurrences do not reflect on the electricity-supply authorities of Oslo. They were due to the unprecedented weather of last summer, which gave the longest drought within living memory.

Norway, indeed, has the highest *per capita* consumption of electricity in the world—a position she has held for many years—and some indication of the ability with which the Norwegian Power Supply Authorities have carried out their task is afforded by the fact that a supply of electricity has been made available to over 98% of the population in a country which is notable for its topographical difficulties. The remote hamlets which receive the benefit of normally abundant power at a cheap rate have to thank not only nature's thoughtfulness in providing an abundant supply of energy in the form of falling water, but also their electrical engineers for so effectively harnessing this energy and bringing it to the majority of remote homes.

Yet, all this having been said and done, the events of late October last year serve to underline how much remains to be done in the water-power field, not only in Norway but in many other countries. Obviously, the water-power engineer has two main tasks: first to harness new energy, and second to improve the "quality" of the energy supplies he has already made available. There is an increasing number of areas supplied by water power where the first of these two tasks is almost completed. Few new major water-power sites remain to be harnessed in those areas, and in spite of the emergence of the bulb-type unit for small installations with low heads, the rate of rise of demand means that water power cannot hope to provide the additional power that future generations will demand.

Yet water power, by providing a stabilising factor on the network, can fulfil a permanently essential function in any power economy. The second of the two tasks therefore becomes increasingly necessary. Attention has to be directed to an ever-increasing extent to the improvement of the storage possibilities of reservoirs, and to the integrating of isolated stations along a given watercourse into a co-ordinated system.

Thus, in the next few decades, the storage possibilities of reservoirs built perhaps twenty or thirty years ago may be completely reassessed.

Man has not so far succeeded in controlling the weather, and it appears unlikely that he will do so for many generations to come, if ever. And so it is up to the hydro-electric engineer to make the best of the weather we receive. Dams have been designed for 100 year floods and it is not considered abnormal to design them with even 1,000 year floods in view. But recent experience in Norway, and indeed in countries such as Spain and Switzerland, shows that the possibility of a few weeks of extra-dry weather has not taken up anything like such a large proportion of the planners' thoughts as the reverse possibility of a few weeks of extra-wet weather. This summer has shown that once in two hundred years some areas do have exceptional droughts, and we have droughts of only slightly less severity much more frequently.

It is hoped that the lessons learned in 1959 will give even greater impetus towards the provision of more water storage. The recent revival of interest in tidal power in Canada and the U.S.A., and the advent of pumped-storage schemes in Great Britain and elsewhere, are other factors which have a bearing on this problem of inadequate storage. The energy for pumping water to a higher reservoir must obviously come from power stations not affected by the drought itself; and this forms yet another argument for the increased interconnection of power networks. Thermal or nuclear stations, in which the load factor must be kept high to provide efficient operation, can, in these days, transmit their power over hundreds of miles, perhaps to areas where the provision of pumped-storage

equipment could well obviate the unfortunate consequences of a drought, and at the same time give both thermal and nuclear stations far better efficiency and commercial performance than would otherwise be possible.

Ever since the birth of the public-supply industry the electrical engineer has been bedevilled by the apparently insoluble problem of storing his product on a commercial scale, and so allowing his costly generating plant to operate at its maximum capability. Only the water-power engineer has ever been able to offer any sort of solution. His special contribution —that of a storage plant which can be put into operation in a matter of minutes—is more urgently needed than ever.

A Hamilton Falls Development

HAMILTON Falls Power Corporation Limited, a subsidiary of British Newfoundland Corporation Limited, is starting construction immediately of a hydro-electric power plant in Labrador. It in turn has set up a subsidiary, Twin Falls Power Corporation Limited, to manage this development. The on-power date for the initial 120,000 h.p. installation is June 1962, with the power being supplied to the Iron Ore Company of Canada and Wabush Iron Company's new iron mining operations and town site in the Wabush Lake area of Labrador. This power plant is to be built at Twin Falls on the Unknown River, a tributary of the Hamilton River which joins it just below Hamilton Falls. The site is about 250 miles north of Seven Islands and 12 miles south-west of Hamilton Falls.

The topography at Twin Falls is unusually advantageous for hydro-electric development. In a three-mile stretch of the river there are two sets of falls, each set in turn being made up of twin falls. The total drop in this distance is more than 400 ft. Running roughly parallel with the river is a dry gorge. The bed of the gorge at its upper end is about 300 ft. below the normal river water level above the falls. The general scheme of development is to divert the river from the plateau level through a canal and penstocks to a power house in this gorge. The catchment area of 8,400 sq. miles will provide an estimated minimum flow of 3,450 cusecs without regulation. At the net head of 290 ft., this can produce 125,000 h.p. firm at 80% load factor. For the initial installation, therefore, the plant will be run-of-river. As the demand increases, up to 12 ft. of storage can be provided in the two large lakes from which the Unknown River flows. The regulated flow in a dry year will then be 8,100 cusecs, sufficient for 300,000 h.p. firm at 80% load factor.

Water will be diverted by a rock-filled timber-crib overflow dam about one mile above the upper set of falls and will pass into a canal approximately 6,000 ft. long. The canal, excavated mainly in earth, is designed to take the flow required for a 180,000 h.p. installation with a maximum water velocity of 2 ft. per sec. It can later be enlarged to carry the flow for a 300,000 h.p. installation. The concrete intake structure will be built with provision for three 60,000 h.p. units. Intakes for two more units can be added later. This structure will be built into an earth dam containing about 470,000 cu. yd. of material. In addition, there will be five small earth cut-off dykes containing a total of about 100,000 cu. yd. The penstocks will be 13 ft. 6 in. in diameter and about 1,600 ft. long. There will be a separate penstock for each 60,000 h.p. unit. The power house will initially contain two units. Rock excavation will be carried out for the ultimate five units. The plant will be designed to operate on local automatic control.

Transmission will be at 230 kV. The line will go by the most direct route to the Wabush Lake area, a distance of about 110 miles. Availability of power and other facilities at Twin Falls will assist subsequent development of the main 4,000,000 h.p. potential at Hamilton Falls.

Bhakra Dam Repairs

MR. J. HATHI, Deputy Minister for Irrigation, Government of India, in a statement made to both Houses of Parliament regarding repairs to the hoist chamber at Bhakra dam, said that the success of the choking operations had exceeded all expectations. The hoist chamber had been completely dewatered and plugging operations had started. All the repair work would be completed before the monsoon begins. The Minister said there would be no appreciable delay in the completion of the dam by reason of the accident to the hoist chamber nor any reduction in the benefits expected from the project.

The left bank power house of the project is expected to go into operation in October this year, and at least 3,300,000 acre ft. of water should be available for irrigation and power during the winter of 1960–61.

Vinstra Power Project Completed

THE second and last generating unit at Upper Vinstra power station, Norway, was recently started up, adding another 75 MW to the capacity of the East Norway grid. This marked the completion of the Vinstra hydro-electric power development, which was started 14 years ago. Lower Vinstra, comprising four generating units, was completed in 1958. Together, the two projects have increased East Norway's power supply by 320 MW. Oslo Municipal Power Company owns two-thirds of Lower Vinstra and one-fourth of Upper Vinstra.

The Lower Vinstra scheme was described in our March and April 1956 issues and the Upper Vinstra scheme in our September 1959 issue.

North of Scotland Hydro-Electric Board

THE annual report and accounts of the Board have now been published for the year 1959. The Board have now 41 hydro-electric stations—all but two of which have been built since the end of the war. During 1959 over 53 MW of new plant were brought into operation and the number of kWh sold to consumers in the Board's area was 1,421 million, an increase of 5·3% since 1958.

The maximum demand on the Board's system was 468 MW—an increase of 31 MW on 1958. The main 132 kV transmission system now extends to 1,795 miles and contracts were being placed for the Board's 275 kV lines.

The Awe project, which was authorised last year, comprises two conventional power stations, Inverawe

and Nant, having a combined capacity of 43 MW, and Cruachan, which is a pumped-storage development, having a capacity of 400 MW. It is expected to be completed in 1966. The estimated completion date for the Strathfarrar and Kilmorack project is 1964. Work which is proceeding on the Loch Glashan project is expected to be completed in 1962.

The programme of the Board's hydro-electric development work has now reached the following stage:—

	MW capacity	Output in millions of units per annum
Works already in operation	866	2,442
At constructional stage	582	911
Under survey	555	1,718

Shawinigan Annual Report

THE 1959 annual report of the Shawinigan Water and Power Company has recently been circulated. Besides dealing with the financial aspects of the company, the report mentions that the seasonal April to June fill-up of the St. Maurice reservoirs was below average. However, precipitation during the summer and autumn was extremely heavy, so that the water storage became 50·5% higher than the long-term average.These favourable hydraulic conditions plus the generating capacity of Beaumont plant, which commenced production late in 1958, permitted the generation of energy in excess of firm-power requirements.

Power growth in the region has been increasing annually at an average rate of 6% and the Shawinigan Water and Power Company have set aside capital outlays to cope with this increase. Their engineering and construction work for 1959 was centred on increasing the capacity of substations and to studies of possible future developments on the upper St. Maurice river. The bed of this river was deepened two miles below the Beaumont power station and brought the plant up to its rated capacity of 246·2 MW. Furthermore, a 230 kV transmission line, 48 miles long, between Trois Rivières and Kingsey terminal stations, and another line 12 miles long between Charlesbourg and Chaudière terminal stations were both completed and commissioned.

India's Third Five-year Plan Projects

INDIA'S third five-year plan will include a number of hydro-electric and multi-purpose projects. The Upper Krishna project, which is estimated to cost about Rs. 80 million, will be designed not only to provide power but to irrigate over 800,000 acres. The question of sharing the Krishna waters with Bombay is now under negotiation, and four possible dam sites are under examination by the Mysore Government.

The Nagarjunasagar multi-purpose project is expected to be completed during this period provided adequate funds were made available by the Indian Government. Andhra State's second five-year plan made a total provision of Rs. 252 million for this project, of which Rs. 252 million have been spent. The budgeted expenditure for 1959–60 is Rs. 85 million.

The construction of the project is being proceeded with on the assumption that the entire scheme is to be completed in one phase. Neither the Government of India nor the Andhra Government have agreed on construction being phased into stages.

By the end of the third five-year plan, the demand for power in Kerala is expected to reach 372 MW. The existing generating capacity will not be able to meet this demand unless the construction of the Pamba-Kakki hydro-electric scheme is speeded up.

Also earmarked for electrification during the third five-year period are some 300 villages in the Delhi territory.

Seventh International Congress on Large Dams

THE Italian National Committee on Large Dams has issued Bulletin No. 1 in connection with the Seventh Congress on Large Dams to be held in Rome from June 26 to July 9, 1961. This bulletin, copies of which can be obtained through the appropriate National Committees, gives outline particulars of the Congress and contains preliminary application forms. The questions to be discussed were given in a note on page 68 of our February issue. It is now stated that papers should be submitted through the National Committees to reach Paris by October 25, 1960. Four alternative study tours are being arranged, to north-western Italy, to north-eastern Italy, to central Italy and Sardinia, and to central Italy and Sicily.

Generators for Benmore

TENDERS are to be called for the six 90 MW generators for the Benmore hydro-electric station, New Zealand. The orders are being offered in an entire group of six, or alternatively for construction of two generators by any one manufacturer.

Progress on the Cávado

THE annual report for 1959 of Hidro Eléctrica do Cávado, one of the three major organisations responsible for the development of Portugal's hydro-electric resources, contains many points of interest. Actually the electricity production, at 598 GWh, was 198 GWh less than that in 1958. In Portugal, however, electricity production throughout the country is controlled by Companhia Nacional de Electricidade on the basis of the economy of the country as a whole, and in view of the favourable hydrological conditions during the year the utmost use was made of run-of-river plants. These conditions are reflected in the figures for the HICA storage reserves, which rose from 300 GWh capacity at the beginning of the year to nearly the full storage of 400 GWh at the end of the year; this was in spite of the fact that the new Paradela reservoir was emptied completely during the year for inspection.

During the year the construction personnel from Paradela was transferred to the Upper Rabagão development and a temporary township established. Preliminary work was done on the diversion of a section of the national road E.N. 103, on the driving of the Alto Cávado/Rabagão diversion tunnel, on the excavation of the machine hall, and on the sinking of two shafts to drive the tailrace tunnel.

Extensive studies were pursued on the potentialities of the Tâmega, Homem and Lima rivers, and on the Island of S. Miguel.

A particularly interesting departure is that an order for an I.B.M. 650 electronic computer was placed dur-

ing the year and should by now be installed. During the previous year use had been made of the I.B.M. Company's Calculating Centre in Paris, and a careful analysis of future demands showed that the purchase of a computer would be abundantly justified.

West Pakistan Authority Report

THE West Pakistan Water and Power Development Authority (WAPDA) came into existence on February 10, 1958, and was fully constituted by the middle of September of that year. The Annual Report for the year ended June 30, 1959, is therefore of particular interest, as it gives an account of the organisation, responsibilities and objectives of the Authority and of the work in progress. The responsibilities cover the development of the water and power resources of West Pakistan on a unified and multipurpose basis, and embrace irrigation, water supply, drainage, power generation, flood control, land reclamation, inland navigation, and effects on public health.

On April 1, 1959, the West Pakistan Government transferred their Electricity Department to the Authority, which thus took over the construction work on various hydro-electric schemes, including Mangla dam (300 MW), Chichoki Mallian (12 MW), Shadiwal (13·2 MW) and Gujranwala (13·8 MW), in addition to the erection of 220 kV and 132 kV transmission systems.

One of the statutory responsibilities of the Authority is to prepare a comprehensive plan for the unified and multipurpose development of the water and power resources of West Pakistan, and the Harza Engineering Company of Chicago have been appointed as General Consultants for this purpose.

Spanish Contract for Britain

AN order worth nearly £2½ million for hydro-electric generating plant for two new Spanish power stations has been won by The English Electric Co. Ltd. against strong European competition. The machinery has been ordered by Hidroelectrica Espanola and will be installed at Valdecanas and Torrejon, both some 120 miles south-west of Madrid. The power stations are the first to be built on the Spanish section of the River Tagus. The 108,000 h.p. pump-turbines at Valdecanas are the most powerful in the world. Total capacity of the two stations will be 400,000 kW which will be fed into the Spanish power network.

Valdecanas, the first stage of the development, will be a pumped-storage scheme, the second largest of its kind in Europe. The largest is at Ffestiniog in North Wales where English Electric are supplying four 105,000 h.p. water turbines.

Delivery of the equipment will start in 1961. Three 108,000 h.p. turbines and three 83,333 kVA alternators are being built for Valdecanas and four 36,000 kVA alternators for Torrejon. All this equipment will be built at English Electric's works at Netherton, near Liverpool. Research and design work on the turbines, using techniques involving complex scale models, was done by the company at Rugby. Associated 230 kV and 138 kV airblast switchgear for distributing the power from the stations will be made at the company's works at Stafford.

The three reversible Deriaz pump turbines operating on a head varying from 160 ft. up to nearly 250 ft. can each produce a maximum of 108,000 h.p. The maximum pumping head will be 240 ft. The turbines will run at 150 r.p.m. and will be equipped with adjustable blades on the runner and adjustable vanes to control the machine load.

The turbines will be coupled to English Electric semi-umbrella type 83,333 kVA alternators. The alternators are designed to operate with reverse rotation as motors and have a pivoted pad-type thrust bearing. High-pressure oil jacking will reduce the starting torque. Magnetic amplifier static voltage regulators will control the excitation of the machines when operating either as generators or motors.

Tunnel Break-through in Snowy Project

ANOTHER stage in the Snowy Mountains hydro-electric project was completed at the end of February by the break-through of the nine-mile Cooma-Tumut tunnel. Contractors used 200 lb. of gelignite to blast through the last 8 ft. of rock. The Australian contractors, Thiesse Brothers, drove the tunnel through in 20 months and in September claimed a world record by driving through 525 ft. of rock in seven working days.

Hydro-Electric Plant for Scotland

TWO orders for waterwheel alternators have been placed by the North of Scotland Hydro-Electric Board with A.E.I. Heavy Plant Division. The machines, one of 15,000 kW, the other of 6,000 kW, will be installed in new automatically controlled power stations. The 15,000 kW alternator, which will be driven by a Francis turbine to be manufactured by the Harland Engineering Co. Ltd., of Alloa, will generate 16,667 kVA at 750 r.p.m., 11 kV, 0·9 power factor. This set is for an underground power station at Livishie, part of the Morriston project, about eight miles north of Fort Augustus, Inverness-shire. Kennedy and Donkin are the consulting engineers for this contract. Commissioning will be in 1962.

The 6,000 kW set, which will generate 6,667 kVA at 500 r.p.m., 0·9 power factor, is for Loch Glashan power station, near Lochgilphead, in Argyllshire. This will be a horizontal alternator, driven by a horizontal Francis turbine, also manufactured by the Harland Engineering Co. Ltd. Strain and Robertson are the consulting engineers for this contract. Commissioning will be in May 1961.

Hydro-Power in Madras State

THE Madras State Electricity Board has drawn up schemes for an overall expenditure of about Rs. 1,360,000,000 for hydro-power development under the Third Five-Year Plan. Practically all the resources in the State for the development of hydro-electric power having been exhausted, schemes under the Third Plan for power development are expected to be either for expansion of the projects already executed or harnessing the watersheds of the Western Ghats.

The schemes now proposed are expected to have a total additional capacity of 475 MW. They are: the Mettur Tunnel scheme, the Parambikulam hydro-electric scheme, the third-stage extensions of the Kundah development; and the fourth unit for the Periyar station.

Fig. 1. Aerial view of Eucumbene dam and Lake Eucumbene

The Tumut I Project

An account is given of the design and construction of the Tumut I project, which forms the second stage in the Snowy Mountains scheme and was brought into operation in October, 1959*

By B. K. JAGGAR, Resident Engineer

PART ONE

THE Tumut I project is the first of a series of five projects to be constructed in the development of the Tumut River. Two of these, Tumut I and Tumut II, are similar in conception in that they utilise long tunnels and underground power stations. The remaining three projects will consist of a power station located at the foot of a high earth and rockfill dam and will not involve the construction of long tunnels.

Tumut I power station has an installed capacity of 320 MW and will operate on peak load with a capacity factor of 32%. The average annual energy output when all headworks are completed in 1963, will be 894 million kWh, and approximately 460,000 acre ft. of water will be made available for irrigation.

The construction work was carried out by two schedule-of-rates type of contracts with escalation for variations in labour and material costs and bonus payments for early completion. The investigation and design was done by the Snowy Mountains Hydro-electric Authority in conjunction with the United States Bureau of Reclamation. To enable contractors to move straight on to the site of the works, essential road access, telephone communications, construction power and accommodation were provided by the Snowy Mountains Authority before the contract was awarded. The project was divided into two contracts for the civil works, one being let in June 1954 to the American group, Kaiser-Walsh-Perini-Raymond, for the construction of Tumut Pond dam and pressure tunnel, the other in July 1954 to a French group of contractors, Etudes et Entreprises, for the construction of Tumut I underground power station, pressure shafts and tailrace tunnel. The value of the civil contracts for the Tumut I project was £A14·7 million, the major part being constructed by the French contractors for £A8·5 million. This article deals only with the Tumut I project, but a short description of the headworks is given to enable full appreciation of the part it will play in the overall scheme.

Headworks

From the map shown in Fig. 2 it will be seen that Tumut Pond is linked with Lake Eucumbene by a 14-mile tunnel in such a way that during periods of high inflow only that water required for power genera-

* The Guthega project, which was the first stage of the Snowy Mountains scheme to be brought into commission, was described in WATER POWER, December 1956, p. 447.

tion is drawn into the power station from Tumut Pond. The surplus water is diverted back to Lake Eucumbene. This enables the Tooma River water, which is diverted by a dam and 9-mile long tunnel to Tumut Pond, to be used either directly for power generation through Tumut Pond or may be diverted back to Lake Eucumbene for storage, depending upon the irrigation requirement. The headwaters of the Murrumbidgee River are diverted directly to Lake Eucumbene by Tantangara dam and a 10½-mile long tunnel.

Eucumbene dam (Fig. 1) which forms Lake Eucumbene is the regulating storage for this project. The dam is an earth and rockfill structure 381 ft. high, with a total fill of 8,700,000 cu. yards and with a gross storage of 3,860,000 acre ft. This dam was constructed for the Authority by the Public Works Department of New South Wales, which supervised a contract for the construction of the embankment awarded to the American group of contractors, Kaiser-Walsh-Perini-Raymond. The storage of the flow from the Eucumbene River commenced in June 1957, and work was completed in June 1958.

The Murrumbidgee-Eucumbene diversion was planned to enable diversion of the flow of the Upper Murrumbidgee River, with almost 100% regulation averaging 248,000 acre ft. per annum to Lake Eucumbene. The gross storage provided by Tantangara dam (Fig. 3) is 205,000 acre ft. This work is now under construction, also by contract, which was awarded to Utah Australia Limited and Brown & Root Sudamericana Limited in May 1958, and is expected to be completed in 1961.

To assist the storage of high flows in the Tumut River, Junction dam and Junction shaft have been constructed (Fig. 4) 100 ft. higher than the maximum water level in Lake Eucumbene. This makes it possible to take advantage of the relatively high head differential for storing the high flows of the Upper Tumut River.

The Tooma-Tumut diversion, consisting of Tooma dam with a gross capacity of 23,000 acre ft. and a 9-mile tunnel, is under construction, having been commenced in May 1958 under contract to an Australian firm, Thiess Bros. Pty. Ltd. Completion of this project is estimated for 1961.

The dam (Fig. 5) is 220 ft. high and is zoned earth and rockfill with a total fill of 1,320,000 cu. yards. The 9-mile tunnel is unlined for most of its length and is of sufficient capacity to divert three times the estimated average inflow into the dam.

Investigation

The conception of the Tumut I project, which consists of a dam, headrace and tailrace tunnels and an underground power station, was clearly indicated by the continuous steep gradient of the Tumut River (123 ft. per mile) downstream from Tumut Pond and the configuration of the river which swings in a large loop of 7 miles, allowing 2½ miles of tunnel to complete the loop. Here the river is narrow, winding through a steep-walled gorge devoid of any terraces or other areas suitable for a surface power station (Fig. 6). For a suitable dam site, it was necessary to balance the economy of a dam and storage consistent in elevation with both the Tooma and Eucumbene diversions, and a clearly economical tunnel and power-station development between suitable tunnel portals for the headrace at Tumut Pond and the tailrace, which was required to be located within a suitable storage for the headworks of the next project downstream. The maximum head utilisation of Francis turbines, considered at that time to be about 1,200 ft., also influenced the determination of the extent of the project.

Five sites for Tumut Pond dam were investigated, and as four of them met the requirements for construction cost and geological suitability, final selection was based on the operation of the pondage as a balancing reservoir and the operation of the power station within the electrical system. The optimum top water level was found to be 22 ft. lower than full supply level at Lake Eucumbene. Both rockfill and concrete arch structures were studied, and cost estimates favoured the concrete arch type.

For the power station the first proposal investigated involved a headrace tunnel, surface penstocks and surface power station with a gross head developed of 1,160 ft. As geology did not favour surface penstocks, because the granite was weathered to a depth of 200 ft., the scheme was extended with a number of alternatives involving sloping and vertical underground pressure shafts with horizontal tunnels leading to a surface power station. These were finally discarded as a practical proposition, as a surge-tank site could not be found sufficiently near to the area which was most

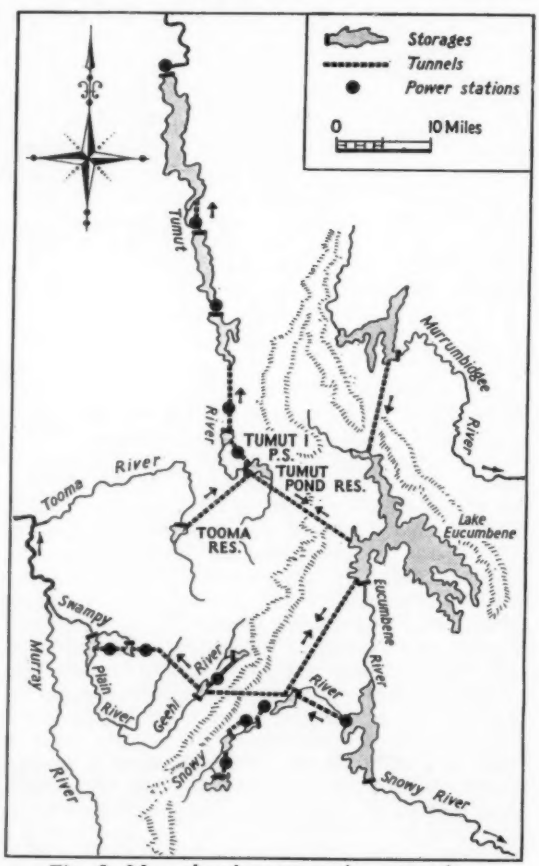


Fig. 2. Map showing reservoir connections

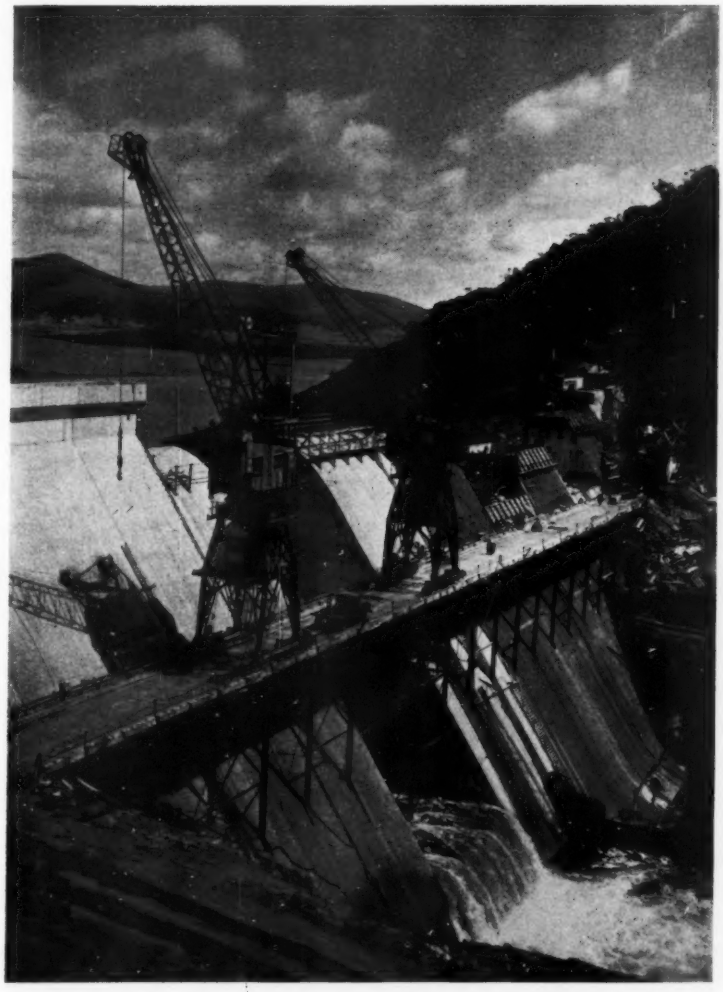


Fig. 3. Tantangara dam under construction

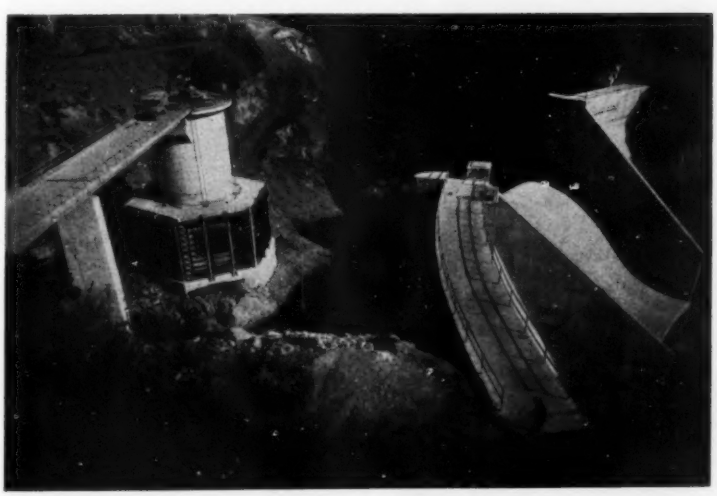


Fig. 4. The Junction dam and intake tower

suitable for the surface power station. Consideration was given also to the construction of an underground power station with vertical pressure shafts immediately downstream of Tumut Pond dam. This was finally discarded because of the long and costly access and the delay this would cause in the construction of the power station. Investigation was finally confined to an 8,000-ft. long pressure tunnel, a two-chamber type underground surge tank, two steel-lined vertical pressure shafts, an underground power station at the foot of the shafts, and a 4,350-ft. long tailrace tunnel.

Design

Under an agreement between the American and Australian Governments, a portion of the scheme was designed by the United States Bureau of Reclamation. Work covered by this agreement included the design of Eucumbene dam, the Eucumbene-Tumut tunnel, Tumut Pond dam and Tumut I pressure tunnel.

Tumut Pond dam, a concrete arch dam standing 283 ft. above the river bed, with a crest length of 817 ft. and a concrete volume of 178,000 cu. yards, was designed by the trial-load method. This design is conventional, with foundation grouting, foundation drainage, drainage and inspection galleries and vertical contraction joints with shear keys. The artificial cooling was accomplished by circulating river water through cooling pipes on the top of each 5-ft. lift. Cooling was performed in two stages, an initial period of 14 days for the purpose of reducing the temperature gradient from exposed surfaces to the centre of the mass and secondary cooling to 44°F. which provides 8°F. subcooling below the mean annual concrete temperature. This secondary cooling was done during the winter months when river temperatures were below 40°F. Contraction joint grouting was done after secondary cooling and when the reservoir was empty.

Tumut Pond dam has the unique advantage that it may be filled and emptied in a few days. Therefore, measurements taken to determine stress due to applied load can provide valuable design data, as the effects of creep, shrinkage and temperature stresses are reduced to a minimum.

The pressure tunnel is completely lined in concrete with steel reinforcement in short sections at the inlet and near the surge chamber. At the inlet, instruments were built into the reinforcing steel to measure the actual stress in the steel in order to ascertain the percentage of load carried by the rock and by the concrete.

The surge tank, of the upper-tank and lower-chamber type, is completely underground and has an orifice below the upper tank to dampen the surges.

Two steel-lined vertical pressure shafts were designed against external pressure, the plate thickness varying from $1\frac{5}{8}$ in. at the bottom to $\frac{5}{8}$ in. at the top. The shafts were instrumented at three points with strain-gauges and pore-pressure cells and it was found that the rock and concrete supported two-thirds of the load from internal pressure and the steel one-third.

The power station is underground and of the high-wall type. The rock surrounding the power station consists of two rock types, granitic gneiss and granite. The granite occurs in sheets 100 ft. to 300 ft. thick intrusive into the gneiss. Both rock types are extensively jointed, and although this jointing is not developed in a very regular pattern, it is possible to distinguish three principal directions. The longitudinal centreline was fixed more or less normal to one of the principal directions, at an angle of 30° to another and parallel to a third. The joint spacing in the granitic gneiss is between 6 in. and 2 ft., generally with some joints smooth and slickensides, and dark green in colour due to thin coatings of chlorite. Because of the nature of the joint surfaces, it was common during excavation for the granitic gneiss to break to the natural joint planes rather than across the rock, resulting in irregular surfaces and small local overbreaks in places. This did not occur in the granite, which was more tightly jointed and fractured closer to the designed lines. Because of this, as much of the power station was located in the granite as possible, leaving only the assembly bay in granitic gneiss.

The most economical arrangement for the power station was found to be one where the main valves, draft-tube gates and busbar ducts were within the

Fig. 5. A view of the Tooma dam site

Fig. 6. Tumut Valley at the site of the power station

Fig. 7. The Tumut Pond dam under construction showing upstream portal of diversion tunnel on right bank

main excavation. This led to a width of 59 ft. With 40 ft. between units, 100 ft. of assembly bay and approximately 50 ft. for the control building, the dimensions of the machine hall became 306 ft. long, 59 ft. wide and 111 ft. high at the deepest point.

The roof of the power station was designed with concrete abutments running the full length of the hall at the springing line of the roof arch and supporting 4 ft. × 4 ft. ribs spaced generally at 12-ft. centres. However, in the granitic-gneiss section 8-ft. spacing was necessary. The ribs were designed on the basis of placing the abutments first. Slots were cast between the rock roof and the ribs, and, after initial shrinkage of the concrete ribs, these slots were filled to ensure intimate contact between rib and rock, which would reduce bending moments which might occur in the rib when loaded.

There are four machine bays, each similar and separated by an expansion joint above main valve-floor level. It was possible to provide free-standing walls above the generator-floor level on the upstream side only without increasing the width of the station, thus providing a relief for water pressure. Where concrete was placed against rock, weep holes were provided. The concrete for the machine bays was broken into two parts. The first-stage concrete was necessary to enable cranes to be installed; this concrete was kept to a minimum, but did include cross-bracing between units.

The transformers are located in a separate hall at right angles to the machine hall and joined by a connecting tunnel which simplifies the intersection of the arches, which were of the same dimensions. A cable tunnel leads from the far end of the hall.

Fig. 8. The Tumut Pond dam completed

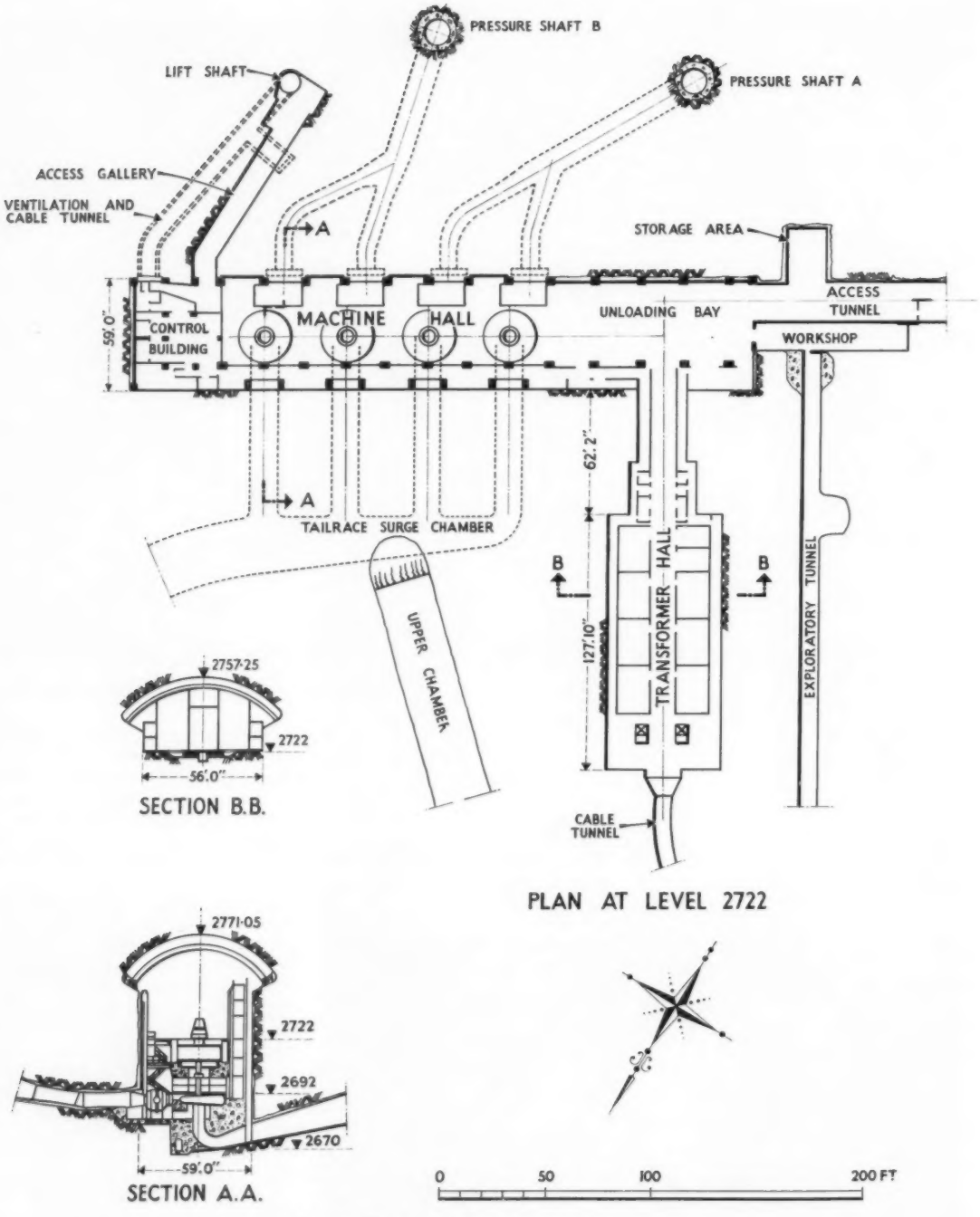


Fig. 9. Tumut 1 power-station layout

Tumut Pond Dam

Tumut Pond dam was constructed using a 16-ton overhead cableway with fixed and moving towers and a hook speed of 1,200 ft. per minute horizontally and 300 ft. per minute vertically over a span of 1,356·5 ft. The river was diverted by a very short tunnel 357 ft. long and was designed to divert 16,000 cusecs, a flood of approximate frequency of 12 years. However, the largest flood encountered during construction was 8,000 cusecs, a frequency of two years.

Work commenced on construction in December 1954, and was completed on April 30, 1959. This time was approximately proportioned as 13 months construction facilities and accommodation, 12 months foundation excavation, 12 months concreting the wall and 3 months grouting. The remaining time com-

prised miscellaneous installation work and clean-up.

The granite foundation was stripped from the top down on both sides of the gorge at slopes between 1½ : 1 and 1 : 1, generally about 20 ft. deep, with hydraulic jets, 1½-cu. yard shovels and muck hauled in 10-cu. yard end dumpers. There was no particular difficulty in the 50,000-cu. yard excavation for the foundation of the dam or in the 90,000-cu. yard excavation for the abutments and spillway. The foundation was grouted, before concreting, on 20 × 20 ft. pattern holes, 30 ft. deep.

Aggregate for concrete was manufactured from diorite and hauled 10 miles to the job. Low-heat cement was hauled 70 miles to the site from the railhead at Cooma. A batching plant with secondary screens and three 2-cu. yard tilting mixers was used for concrete production. Entrained air was used in all concrete and at times heated water and calcium chloride up to a maximum of 2% by weight of cement was used in winter months. Concrete was handled in 6-cu. yard pneumatically controlled bottom-discharge buckets which were charged at the batching plant ⅓ mile from the dam and carried by flat-topped trucks to the cableway.

Gravity thrust blocks at each end of the arch were constructed first, together with stages of the spillway construction where the first concrete was placed by H.R.H. Prince Philip on November 27, 1956. The total volume of concrete in the dam and spillway structure is 184,520 cu. yards. The best placing rate of concrete was 600 cu. yards in a shift, 1,578 cu. yards in a day and 8,710 cu. yards in a week. In the best month 33,540 cu. yards of concrete was placed.

The 15 blocks of the dam were placed on 5-ft. high horizontal lifts, each block being 47 ft. 6 in. long on the axis of the dam. Each vertical construction joint was pressure grouted in 50-ft. lifts. Provision for grouting the joints was 1½ in. diameter supply and return lines with vertical take-off pipes provided with outlets giving a 10 ft. × 10 ft. pattern on the face of the joint.

The centre point of each block was located by triangulation from fixed points to an accuracy of plus or minus ¼ in. From this mark the steel forms were set. Three different mixes were used. On the upstream face a 0·45 water/cement ratio concrete was used, 0·5 water/cement ratio was used on the downstream face, and the mass concrete was controlled on a strength basis of 3,800 lb. per sq. in. at one year. All concrete had a maximum size aggregate of 6 in.

(To be continued)

Vaiont Dam Three-quarters Complete

The construction of the Vaiont dam, which is claimed to be the highest arch structure in the world, reached three-quarters of its height at the end of the 1959 working season.

The dam, which was described in our June 1958 issue, is located near Belluno, North Italy, and belongs to the Società Adriatica di Elettricità, Venice. Excavation was carried out in 1957 and completed in the first half of 1958, involving the removal of 400,000 cu. m. of material. Concrete pourings were begun in summer 1958 and were regularly and rapidly carried on throughout the 1959 working season. In November 1959 the dam reached an average height of 207 m., the prospected height being 261·50 m.; thus the Vaiont dam is already one of the highest structures of any type now in existence. The concrete volume poured at that date was 298,000 cu. m. against the 360,000 cu. m. in prospect.

Part of the prospected grouting was also carried to completion. This includes a large grouting screen which extends both under the foundation and in the abutments.

Concrete pourings are starting again this spring, the completion of the dam being scheduled for the end of the summer.

All the supply works for the reservoir have also been practically executed. The reservoir will be fed partly by its own catchment area, partly by the existing supply tunnel of the Piave-Boite-Maè-Vaiont hydro-electric scheme (to which the dam belongs), and partly by a supply tunnel built specially. The latter, which is now being completed, includes a dam at Vodo on the Boite mountain torrent, and a 9 km. tunnel. The new Vodo dam, which is used for taking in this stream, is 42 m. high, with a chord of about 50 m. and a volume of 6,800 cu. m. Although comparatively small in size, it is noteworthy for it is an unusual, sharply-curved structure. Its construction was practically completed at the end of the 1959 working season, marking a new achievement among the numerous, interesting arch structures in the Italian Eastern Alps.

The construction of the auxiliary works for the Vaiont reservoir is also far advanced; among them is the complex reservoir-emptying system, which consists of a bottom discharge, a half-height discharge, and a surface discharge, and the various tunnels which connect the reservoir to the Piave-Boite-Maè-Vaiont scheme.

The reservoir will improve the output of the Soverzene power station, already operating, about which information was given in our March and April 1954 issues. A small power station, at the foot of the dam, is also nearing completion.

Self-Priming Water Pumps. Leaflets recently circulated by Ransomes and Rapier Limited, 32 Victoria Street, London, S.W.1, give interesting performance details on the following Rapier self-priming water pumps: The 3P18, 4P25 and 2P10.

The Workability of Concrete. The January issue of a publication of George Wimpey and Co. Ltd. contains an eight-page leaflet (Research and Application No. 11) on the workability of concrete, one of the researches carried out by the Wimpey Central Laboratory. The paper presents a method of assessment which enables an estimate to be made of the compacting factor to within ±0·02. It also throws further light on the effect of size particle and shape, the influence of mix proportions, absorption by the aggregates and the time factor. From the experiments carried out, some of the results of which are in tabulated form, considerable evidence has been presented to show that the compacting factor can be calculated to a reasonable degree of accuracy from the characteristics of the aggregate-mix proportions and the water-cement ratio.

The Water-Jet Pump-Its Use in Hydro-Electric Schemes

In hydro-electric schemes where fluctuations in tailwater level are substantial and cause a loss of power production, it is suggested that a jet pump be installed in the draft tube to make good this loss. Such a pump would use only surplus water

By R. SILVESTER, B.A., B.E., Ph.D.(W.A.), A.M.I.E.(Aust.)

ONCE the best sites are developed for hydro-electric power, the more difficult sites will come in for consideration. With the passage of time smaller heads must be utilised which are residuals from existing plants, or are part of main river systems where levels must be maintained for navigational or other purposes. Tidal power also is becoming an economic proposition. In all such systems the meagre and variable nature of the heads present many problems in turbine selection and control.

As the variation in head is generally associated with surplus water, as, for example, flood periods with normal plants, or limited time of utilisation in tidal plants, it would appear feasible to use the energy of this water to reduce the effect of the lost head. It is submitted that a water-jet pump installed in the draft tube would make up part of this loss by providing a suction on the turbine and a positive pressure at the draft-tube outlet to offset the higher level of the tailrace.

Historical

Previous attempts to utilise part of the energy in flood discharges, to compensate for the excess tailwater head, have been well summarised by Mosonyi[1]. These "head increasers" assumed three forms (see Fig. 1) in which the flood water

(a) was jetted through the draft tube by means of ejector channels;
(b) was channelled between turbine units and over the draft-tube outlets;
(c) was released through spillway chutes over the turbines and the draft-tube outlets.

Alternative (a) appears at once to be a very inefficient type of mixing chamber for the high- and low-velocity jets and was well termed a "confusor." Alternatives (b) and (c) both resulted in a roller formation, tending towards a hydraulic jump, which maintained a lower pressure on the draft-tube outlet than if the full tailwater head were exerted on it. Mosonyi has reported that alternative (c) had proved the most successful of the three.

Drawbacks in the proposal were the high cost of constructing the chutes and making the power house watertight.

Also the gain in head could not be assessed accurately because of friction and eddy losses. Gibson[2] conducted model tests on this type of "backwater suppressor" and concluded that: "The real gain of head is in general appreciably less than the apparent gain based on the difference in level between the trough of the standing wave and the level at the end of the tailrace. This is due to the fact that the pressure

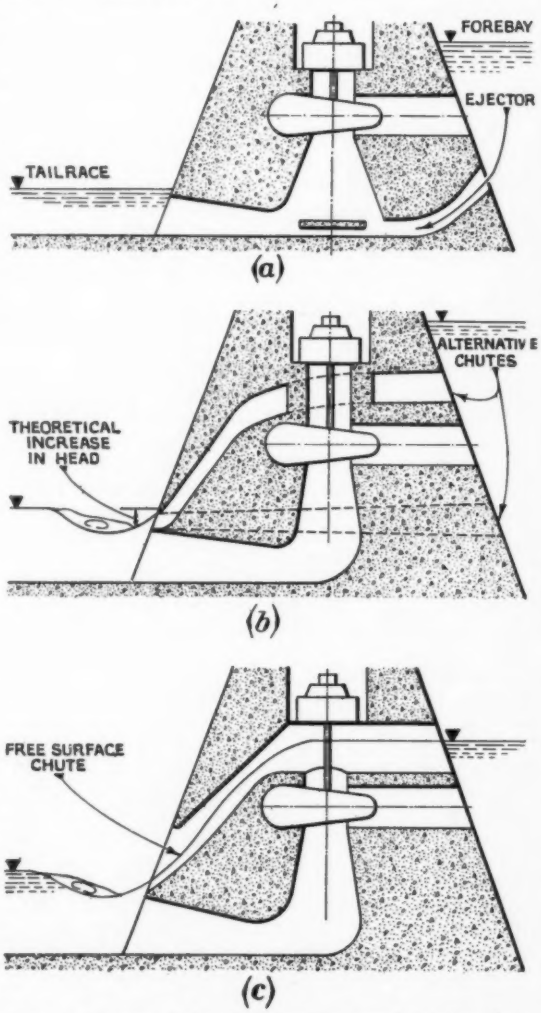


Fig. 1. Types of head increasers used previously

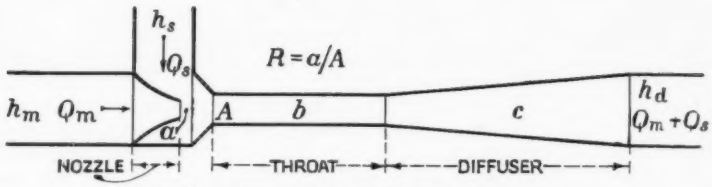


Fig. 2. Diagrammatic section of jet pump

at the outlet from the draft tube is greater than that corresponding to the level of the water surface in its vicinity, the excess pressure being due to centrifugal action accompanying changes in the direction of flow in this region." Even so, Marquenet[3] reports a recent installation of a backwater suppressor.

The only reference to a draft-tube ejector, of the type suggested by the author, is given by Mosonyi in his report on alternative (c) above: "This solution, patented by Koechlin, was first adopted for the Kembs power plant (Rhine, Grand Canal d'Alsace, France). Effects of the Koechlin chutes, according to the original plans, were to be improved by so-called Freemann ejectors; yet the installation of the latter was discarded."

It seems as though the use of flood discharges has been side-tracked because of the relative inefficiency and costly installation of what, in essence, is a free-surface diffuser. On the other hand, the ejector pump has been used by the mechanical engineer for decades, and even though the maximum efficiency so far obtained is in the region of 40%, it seems obvious that it must exceed that of the head increasers described above.

In general, most of the research conducted to date on ejector pumps has been on small models. It has been shown[4] that the larger the pump the higher the efficiency.

Not only is there a dearth of information on large jet pumps, there is also a need for much more research into the general characteristics. Even today the design of an ejector pump for any specific load condition is still somewhat empirical, and this possibly has deterred the civil engineer from applying it in large installations.

Jet-Pump Characteristics

The ejector pump, of which the water-jet pump is a special case, transfers energy from one fluid at high pressure to another at a lower pressure, delivering the total flow of driving and driven fluid at some intermediate pressure. This transfer of energy is accomplished by turning the high pressure into velocity by means of a nozzle and by turbulent mixing with the low-pressure fluid in a mixing tube or throat. The resultant velocity is then reconverted to pressure energy by means of a diffuser.

As seen in Fig. 2, the main items of such a pump are *a* the nozzle, *b* the mixing chamber or throat, and *c* the diffuser. In the design of a pump, such variables as the length of the throat, its entry shape, the nozzle-to-throat distance, and the diffuser angle, are important in obtaining optimum efficiency. But the main proportion which affects the head-discharge relationship is that of the nozzle/throat-area ratio R.

The variables in operating the water-jet pump are as follows:

Q_m the discharge of the driving liquid

Q_s the discharge of the driven liquid

h_m the head behind the nozzle which produces Q_m

h_s the head at which Q_s enters the pump

h_d the head at which discharge (Q_m and Q_s) is delivered.

The heads are gauge pressures plus velocity heads. They are negative if below atmospheric pressure. In the ratios to be used velocity heads are likely to cancel out.

There are two methods of computing efficiency, which give different results. The first is:

$\eta = \dfrac{(Q_s + Q_m)\ h_d}{Q_m\ h_m + Q_s\ h_s}$ based upon total energy into and out of the pump.

The second is:

$\eta = \left(\dfrac{Q_s}{Q_m}\right)\left(\dfrac{h_d - h_s}{h_m - h_d}\right)$ based upon the total energy used and the work done.

Since the first is dependent upon the elevation datum, it is not a satisfactory index of performance. The second does not suffer from this disability and will be used; it can be replaced by $\eta = M\ N$ where M and N are simply the discharge and head ratios that they replace.

The general characteristics can be expressed in a graph of M versus N on which the iso-efficiencies ($M \times N$) can be drawn as soon as the scales have been chosen. This is illustrated in Fig. 3. It can be seen that a separate efficiency diagram is not required.

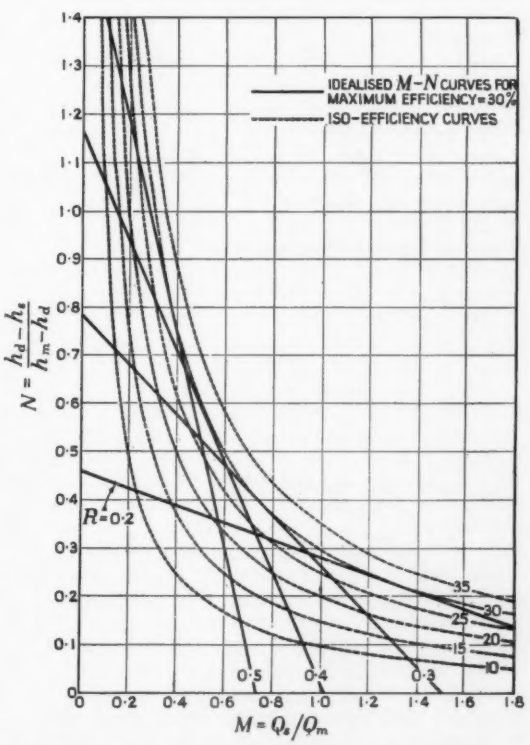


Fig. 3. M-N *characteristic of jet pump with iso-efficiency lines*

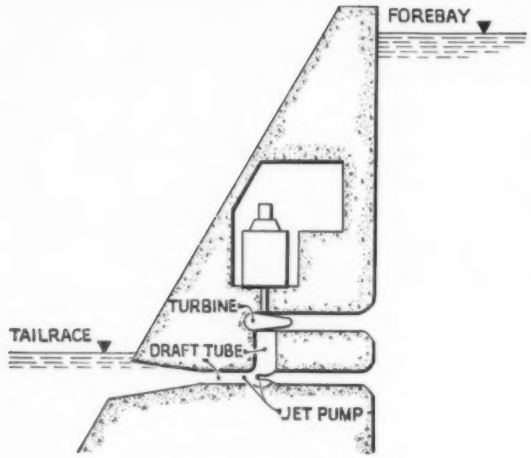


Fig. 4. General features of a draft-tube jet pump

In fact, efficiencies need not be calculated because the plottings of M and N values will give this information directly by means of the iso-efficiency curves.

For any given pump the M-N relationship is almost linear, concaving upwards slightly. The general slope of this line is determined by the nozzle/throat-area ratio R, irrespective of the scale of the pump. The location of the curve (and hence the efficiency) is determined by the many factors enumerated above as well as the Reynolds number of the nozzle discharge. The straight lines in Fig. 3, giving a maximum efficiency of 30%, have been drawn from data presented in reference No. 4.

As the suction discharge Q_s depends upon the suction head h_s generated and also upon the characteristics of the suction line, the water-jet pump is limited in suction ability in a similar manner to centrifugal pumps. These limitations will not be discussed here because they can easily be overcome by locating the pump at a suitable level.

Reaction Turbine Installations

In the design of a reaction-turbine scheme the total head available is the difference in level between the headrace and the tailrace. These levels vary, but the variation of the tailrace is generally greater as this rises during flood conditions and falls during droughts. The lowest tailrace level generally determines the elevation of the turbine, so that it will work to the limit of its suction capacity without cavitation.

During a flood a rise in the tailwater level reduces the suction head applied to the draft tube and this head is lost in regard to the production of power. On these occasions, also, water may be wasted over the spillway or through relief valves. A jet pump installed in the draft tube, as illustrated in Fig. 4, using some of this surplus water could maintain the suction on the turbine and provide pressure at the draft-tube outlet to withstand the higher level in the tailrace.

Such an installation may permit the turbine to be lowered, thus increasing the positive head on the machine; the reduced suction head could then be made up on the odd occasions of the rising tailwater. It could be envisaged that an automatic control of the flow through the nozzle of the jet pump could maintain a constant head on the machine. Such a control would only operate when the headrace level indicated surplus water and the tailwater conditions required it.

Where barrages are thrown across rivers to maintain certain backwater levels for navigational or irrigational purposes, small heads are available for power production. All of the river flow cannot be harnessed because of the fluctuations in level that would result from normal power demand. Draft-tube jet pumps would permit a higher total head to be applied to the turbines until all this surplus water was utilised. Under normal conditions the jets would be partially open and on the occasion of flooding fully open.

In a tidal power plant the headrace and tailrace levels are changing continuously, and the draft-tube pump would, in essence, add height to the dam as well as give a more constant head on the turbines. Extra discharge does not affect the headrace level greatly in comparison with the swift changes in the tailrace.

Impulse Turbine Installations

Because of the large heads generally involved in a Pelton wheel scheme, and the nature of the flow from the turbine under atmospheric pressure, the jet pump cannot provide quite the same benefits as for the reaction turbine. But the turbine is set as low as possible commensurate with the highest tailwater level. Such a flood level may occur very infrequently and in the meantime several feet of head may be lost due to the required elevation for such occurrences.

In discharging the spent water to the tailrace a jet-pump feature would cater for these infrequent adverse conditions. This might permit the wheel to be lowered and to give extra head for the remainder of the year without use of the jet pump.

Of course, some of the supply water to the turbine would have to be used for the jet, requiring some power to be lost at this period. Such a loss would have to be balanced against the gain in power production due to the extra head available over the year.

Design of Draft-Tube Pump

The variables important to the design of the pump are:

Q_s = the discharge through the turbine

h_s' = the head at exit of the turbine—this has a maximum negative value[5] equal to $h_a - h_v - \sigma h_t$

Where h_a = the atmospheric pressure head

h_v = the vapour pressure head

σ = the cavitation coefficient which varies with the specific speed of the turbine

h_t = the net head on the machine

h_d = the head of water on the draft-tube outlet

h_m = the head of water applied to the nozzle $= h_1 + h_2$.

These variables are shown in Fig. 5.

Let the net head on the turbine h_t be increased by a fraction k, that is, by kh_t

then $h_s' = h_1 - (1+k)h_t$

and $h_s = h_s' + h_2 = h_1 - (1+k)h_t + h_2 = h_m - (1+k)h_t$

thus $N =$

$$\frac{h_d - h_s}{h_m - h_d} = \frac{h_d - h_m + (1+k)h_t}{h_t} = \frac{(1+k)h_t - h_t}{h_t} = k.$$

From the M-N graph for $N = k$ and optimum efficiency of 30% (Fig. 3), M and R can be found.

Q_m can then be computed, knowing the value of Q_s.

The nozzle area is given by:

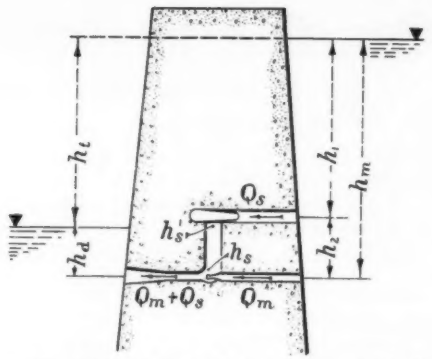


Fig. 5. Variables involved in design of draft-tube pump

$$Q_m = A_j\ C_d\ \sqrt{2g\ (h_m - h_s)}$$

where A_j is the nozzle area
C_d is the coefficient of discharge
g is acceleration due to gravity.

The throat area is then A_j/R.

The length of the throat should be approximately six times its diameter[6]. The included diffuser angle should be in the region of 10°. The nozzle-to-throat distance should be one throat diameter[6]. For small jet pumps the best value for this distance was found to be one nozzle diameter[7]. There is scope for further research into all aspects of jet-pump design.

Some Examples

Example 1. A reaction turbine designed for a net head of 100 ft. and using 500 cusecs is set 20 ft. above the lowest tailwater level, which in flood conditions rises 25 ft. This reduces the net head by 15 ft. as the headrace level rises 10 ft. above the normal on which the net 100 ft. was based. It is required to design a draft-tube jet pump to maintain 100 ft. net head on the turbine.

Fig. 6 shows the probable layout. Under normal flood conditions the head on the turbine is 85 ft. It is required to increase this to 100 ft., that is, $k = 15/85 = 0{\cdot}177 = N$.

To check this $h_m = 112$, $h_d = 27$, $h_s' = 90$–100, $h_s = -10+22 = 12$

hence $$N = \frac{h_d - h_s}{h_m - h_d} = \frac{27-12}{112-27} = \frac{15}{85} = 0{\cdot}177.$$

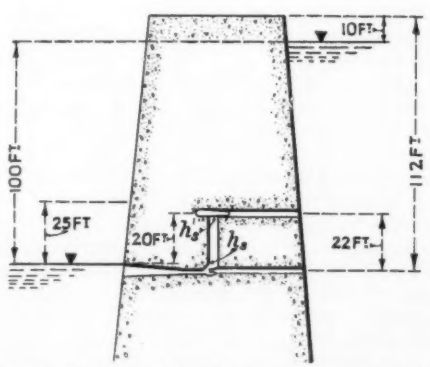


Fig. 6. Details of installation for example 1

From Fig. 3, $M = 1{\cdot}7$ and $R = 0{\cdot}175$, thus:

$$Q_m = \frac{500}{1{\cdot}7} = 294 \text{ cusecs.}$$

The nozzle area is given by:

$$294 = A_j\ 0{\cdot}95\ \sqrt{2g\ (112-12)}$$

i.e. $A_j = 3{\cdot}88$ sq. ft. and $A_t = 3{\cdot}88/0{\cdot}175 = 22{\cdot}2$ sq. ft.

Example 2. A tidal power scheme working on the ebb-tide system[8] has a tidal range of 35 ft. The turbines are to be designed for a normal gross head of 25 ft. and will be kept in operation down to a head of 7 ft. It is desired to see what benefits a draft-tube pump could introduce, assuming that the discharge through the turbines remains constant.

If it were desired to increase the initial head of 7 ft. to 10 ft., then $k = \frac{3}{7} = 0{\cdot}43 = N$. From Fig. 3, $M = 0{\cdot}7$ and $R = 0{\cdot}33$.

$Q_m = Q_s/0{\cdot}7 = 1{\cdot}43\ Q_s$ and the total discharge be-

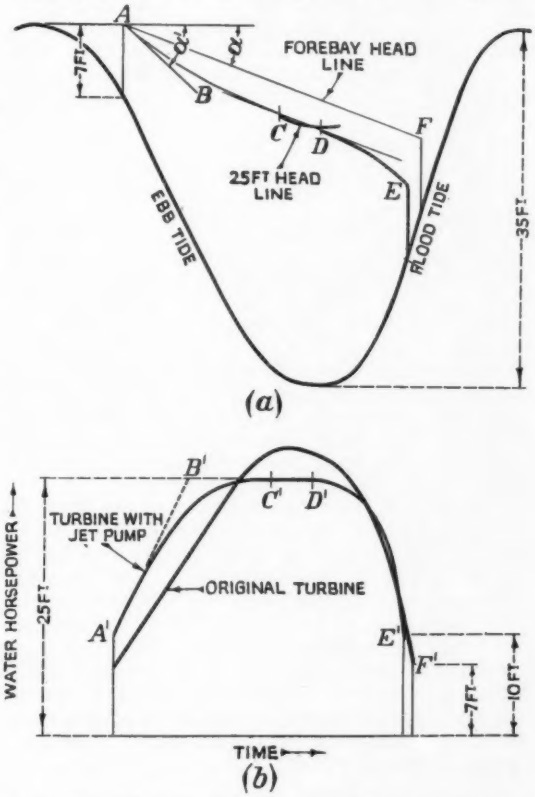


Fig. 7. Power curves for tidal power plant (example 2)

comes 2·43 times the original discharge through the turbines.

Referring to Fig. 7, the discharge from the forebay is proportional to tan α (assuming a linear relationship between forebay area and forebay level). The new discharge is thus given by a line at angle α′ such that tan α′ = 2·43 tan α (line *AB*).

When the available head reaches 25 ft. no flow is required through the jet pump and hence at point *C* a discharge line can be drawn parallel to the original. Between points *A* and *C* decreasing values of *k* (and

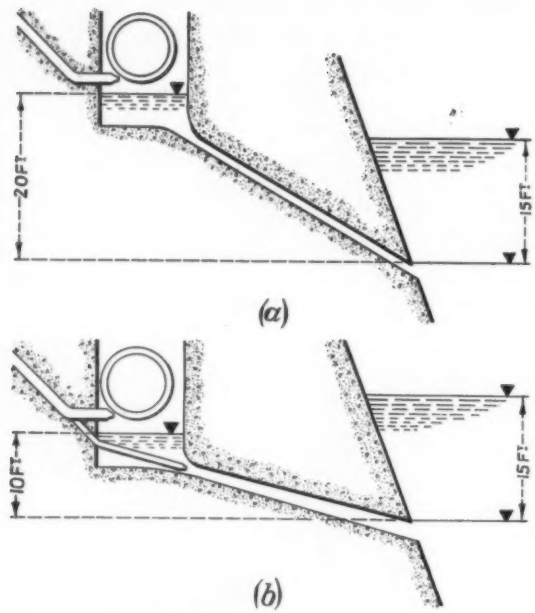


Fig. 8. Details of Pelton-wheel turbine in example 3

hence N) are needed for smooth operation making M increase along the $R=0{\cdot}33$ line. This would be accomplished by placing a valve in the nozzle line and so reducing h_m. An adjustable nozzle might be used resulting in a higher efficiency for the jet pump[4]. In any case a specific M-N curve must be followed.

At point D the head starts to decrease and the jet pump would slowly come into operation until at point E it is fully open and discharging 1·43 times as much as the turbines. The turbines could be closed down when the head reaches 10 ft. or 7 ft., the time interval between these values being small.

The horsepower available varies as the head, for constant discharge, hence the total energy available for the tidal cycle is given by the areas under the curves of Fig. 7*b*. Since the turbine and alternator efficiencies are reduced when off their peak load[8], a true comparison of each type of operation can only be gained by including such data.

Thus the main benefits of the draft-tube pump is the longer period obtained at the design head and the smaller variation from this head. Any total increase in energy could only be ascertained by analysing a specific scheme.

Example 3. A Pelton wheel operates under an effective head of 400 ft. and discharge 20 cusecs. After leaving the turbine the flow passes through a pipe, 30 ft. long, to a tailrace, the level of which rises 15 ft. during flood conditions. The wheel is set 20 ft. above the normal tailwater to allow for the flood level. The problem is to design a jet pump to enable the turbine to be lowered 10 ft.

The original scheme may be as sketched in Fig. 8*a*. With 5 ft. head allowable to discharge 20 cusecs, a 13 in. pipe would be required. In the design of the jet pump it will be assumed that the flow through the turbine remains unchanged.

Referring to Fig. 8*b* we have $Q_e=20$ cusecs, $h_m=40$ ft. (say), $h_d=10$ ft. (say), $h_s=5$ ft. (say).

$N=\dfrac{10-5}{40-10}=\dfrac{5}{30}=0{\cdot}17$ for which (Fig. 3) $M=1{\cdot}8$ and $R=0{\cdot}17$. $Q_m=20/1{\cdot}8=11{\cdot}1$ cusecs, thus $11{\cdot}1=A_j\,0{\cdot}95\,\sqrt{2g\,(40-5)}$, that is, $A_j=0{\cdot}24$ sq. ft. ($d=7$ in.) and $A_t=0{\cdot}24/0{\cdot}17=1{\cdot}5$ sq. ft. ($d=17$ in.).

The jet may have to be sited at a lower level should the drawdown cause suction of air, in which case N and the general proportions of the pump would change.

Conclusions

The sample calculations given above illustrate the feasibility of using the water-jet principle in hydro-electric schemes. In spite of its inefficiency, this type of pump can assist in restoring lost head by using otherwise wasted power. Although simple in design, it implies certain structural features in a power plant, the cost of which must be included in the assessment of the economies effected from the extra power produced. It certainly has advantages over the backwater suppressors used previously.

Should the jet pump come into general use, in this and other fields, it would receive its due attention in research programmes, from which an increased operational efficiency is sure to emerge, especially in the larger sizes.

REFERENCES

1 E. MOSONYI: "Water Power Development." Publishing House of Hungarian Ac.Sc., Budapest, 1957, Chapter 56.
2 A. H. GIBSON: "An Investigation of the 'Backwater Suppressor' as Applied to a Hydro-Electric Installation," Selected Eng. Paper No. 92, Inst. Civil Engrs., 1930.
3 G. MARQUENET: "The Use of Floods for Head Maintenance at the Faux-la-Montagne Power Plant," *La Houille Blanche*. No. Special A, May 1951, p. 268.
4 A. J. STEPANOFF: "Centrifugal and Axial Flow Pumps," 2nd Ed. John Wiley & Sons Inc. N.Y., 1957, Chapter 18.
5 D. ZANOBETTI: "Characteristics of Francis Turbines," WATER POWER, March 1959, p. 96.
6 A. G. BEALES and R. M. PERRY: "Jet Pump Characteristics." Thesis in Engineering, University of Western Australia, 1953 (unpublished).
7 J. E. GOSLINE and M. P. O'BRIEN: "The Water-Jet Pump," University of California, Publ. Vol. 3, No. 3, 1934, p. 167.
8 H. HEADLAND: "Tidal Power and the Severn Barrage," *Jr. Inst. Elect. Engineers*, Vol. 96, Part 2, 1949, p. 427.

Compressors and Rockdrills. Recent illustrated brochures have been issued concerning the Airvane 600 and Airvane 365 rotary portable compressors, the WN 112 air compressor, and Speedline rockdrills—all of which are manufactured by the Air Power Division of Joy-Sullivan Limited, 7 Harley Street, London, W.1. The technical information contained therein gives the types, properties and uses of such equipment in their respective fields.

Telcon Metals Limited. British Insulated Callender's Cables Limited announce the formation of a new Company, Telcon Metals Limited. This Company, centred at Crawley, will assume responsibility for all the activities of the Metals Division of The Telegraph Construction and Maintenance Co. Ltd. These cover the manufacture of Telcon magnetic materials and other special alloys used in the electrical and engineering industries and also the advanced metallurgical operations associated therewith.

Designing Low-Cost Transmission Lines

A careful assessment of the factors influencing the design of a high-voltage transmission line can have an important influence on transmission costs

By LAURI HARO* and PENTTI HAAPANEN*

THE relative importance of the transmission line cost in the price of electrical energy depends upon the conditions in the country concerned. If the power plant can be situated in the neighbourhood of the load, a relatively low transmission voltage appears to be the most economical means of supply, and as a whole the transmission cost is of less importance. If, on the contrary, the power plant has to be placed far from the consumers, high voltages are required, and any savings in line construction are worth consideration.

The order of the costs involved nowadays in new hydro power projects is given in Table I, the prices being based upon Finnish conditions. Three different assumptions have been made as regards the distances of transmission: 100, 400 and 700 km., the transmitted power being 1,000 MW. Within the limits of variation chosen in this example, the line cost increases from £2·7 millions to £11·2 millions. The existing conditions in Finland approximately correspond to the figures 1,000 MW and 700 km., which means that economical line design can save a substantial sum of money.

Costing the Line

When designing a new transmission line, the quantity of power and the distance from the source of the energy to the consumer usually determine the applied voltage. The existing system, however, sometimes dictates a solution that would not come into consideration if a start were made from the beginning. What generally happens is that the line designer gets from the system planner a hand of cards to play with, and among these cards are the transmission voltage, the end points of the line, the length of the line, and the type—single or double circuit. Economic considerations, and sometimes "philosophy" as well, lead to a certain choice of conductor, type and material of the structures, insulation level, lightning protection, mechanical safety level, span length, and detailed route; and every one of these factors can be employed by the line designer to affect the price of the line.

The average price level on which we work today in Finland is given in Table II. The rough subdivision of the line cost gives some idea of the various opportunities available for reduction of the total cost.

Conductors seem to be the most tempting component, but unfortunately very little can be done as far as these are concerned. The overall economy of the system has dictated the use of high voltages, and this in turn usually determines the choice of the conductor diameter. If the system allows a moderate voltage, the cost of the losses in the conductors puts a lower limit on the cross-section of the conductor. As a conductor material, aluminium is nowadays superior to all other metals; usually, conductors have steel strands as reinforcement. Alloys of aluminium with the addition of silicon and magnesium have been used with or without steel reinforcement in some countries.

The towers are the next biggest item. If the line is built with self-supporting towers, their percentage cost on a single-circuit line is even larger than that given in Table II. Of the remaining cost components, the items "transport and machines" and "wages" are bound up with the design of the supports. When the towers are welded together into a small number of larger parts, the cost of assembly is partly paid for in factories, and the size of the parts again affects the

TABLE I.—PRICE COMPOSITION OF HYDRO-POWER PROJECTS IN FINLAND
(The power developed and transmitted 1,000 MW)

Transmission distance, km.	100		400		700	
Cost	Million £	%	Million £	%	Million £	%
Power stations	110·0	96·4	110·0	90·6	110·0	86·6
Switchyards and transformers ...	1·4	1·2	5·0	4·1	5·8	4·6
Lines	2·7	2·4	6·4	5·3	11·2	8·8
Total	114·1	100·0	121·4	100·0	127·0	100·0

* Respectively Director of Transmission Line Department, and Engineer in Transmission Line Department, Imatran Voima Osakeytiö, Helsinki, Finland.

TABLE II.—COST OF LINES RECENTLY BUILT IN FINLAND

Line voltage	110 kV		220 kV		400 kV	
Cost	£ per km.	%	£ per km.	%	£ per km.	%
Wages	450	16	419	9	605	8
Transport and machines	359	13	398	9	633	8
Material—						
Towers	609	22	1046	23	1590	20
Conductors	783	28	1644	36	3452	43
Earth wires	—	—	160	3	160	2
Insulators	147	5	179	4	417	5
Other	58	2	72	2	120	1
Miscellaneous	157	5	171	4	295	4
Total	2563	91	4089	90	7272	91
Interest on construction time	107	4	297	6	526	7
Area for right-of-way	156	5	167	4	189	2
Total	2826	100	4553	100	7987	100

transport cost. The most economical overall solution naturally depends upon the local conditions, such as the terrain, the existence of roads, transport facilities, the wages paid for different types of work, etc. As a whole, the three factors "towers," "wages," and "transport and machines" are those which most decisively affect the line cost. All the remaining costs of actual construction are of such a nature that they are subject to very little control by the designer. The omission of earth wires means some savings, but their importance depends upon the local conditions. "Insulator" cost is mostly determined by the prices of the insulators themselves, and also by the accessories. "Others," "miscellaneous" and "area for right-of-way" depend to such a large extent on the conditions that their magnitude is also beyond the reach of the designer.

The length of the period of construction determines the interest cost on capital before the completion of the line. The normal procedure in Finland is that of apportioning the work from 8 months to 2½ years, dependent on the voltage and the length of the line. If the decision relating to a new project is made in good time, the construction period can be shortened, but the decrease of the interest cost is so small that the savings gained may be lost in the increased need for supervisors.

Operational Safety and Faults

The network of Imatran Voima Osakeyhtiö comprises 4,000 km. of lines of 110 kV or above. During the period 1950–1958, the total number of faults was 568, of which 71% were caused by lines. In this connection, "a fault" means disturbance which either leads to interruption of energy supply, or is only noticed by the aid of measuring instruments. The direct loss of income due to the interruptions in service is very small, because most of them last but a few minutes. Thus, the amount of energy not supplied to consumers as a result of interruptions was only 0·013% of the total energy sold during the period in question. Nevertheless, despite this industry may experience difficulties, if the supply of energy is subject to frequent interruption, even if they are short-lived. Pulp and paper mills are especially sensitive to interruptions because a break of one minute may involve a loss of half an hour in production.

The correct way to consider the worth of the safety for a large-scale utility is to estimate the cost of the service interruption from the point of view of the national economy, but the difficulty arises when this amount is being calculated. In practice, it is easier to estimate how much the "safety" costs. For instance, we can take two different designs, and calculate the probable number of annual faults for each of them. When comparing the difference in cost of the two solutions with the respective numbers of probable faults, one gets a rough idea of the cost of the safety.

Table III contains the service statistics for the lines of Imatran Voima Osakeyhtiö during the years 1950–1958. Lightning causes 77% of the faults on the 110 kV lines, and 82% on the 220 kV lines. Weather conditions in general, such as ice loading and wind, are also sometimes the origin of faults. Faults brought about by ice loads are actually caused by inadequate design. On certain lines the earth wires were placed too close to the outer phases in the horizontal direction, and the remedy applied was to move them in the direction of the middle phase. The instances attributed to the insulators have their origin in defects of material, and those relating to the conductors mostly in bad work on the site.

Accidental or malicious damage is sometimes caused to the lines by outside agencies. In densely

TABLE III.—FAULTS ON THE LINES OF IMATRAN VOIMA OSAKEYHTIÖ, 1950–1958

Cause of fault	Weather						Material or constructional defect				Accidental or malicious damage		Unknown		Total	
	Lightning		Wind		Iceload		Insulator		Conductor							
	*	%	*	%	*	%	*	%	*	%	*	%	*	%	*	%
Lines																
110 kV ...	1·87	76·9	0·06	2·3	0·04	1·7	0·10	4·3	0·08	3·1	0·03	1·1	0·25	10·6	2·43	100
220 kV ...	0·53	82·1	—	—	—	—	0·03	5·4	—	—	0·05	7·1	0·03	5·4	0·64	100

* % per 100 km. per annum.

populated countries, aircraft crashing against the lines may also cause faults, but in Finland this kind of damage is so far unknown. In one instance, the tow-rope of a gliding plane did in fact cause an earth fault.

For selection of the safety level the line designer needs information as to the local conditions on the proposed route. The best source of information is the service experience gained from existing lines, but this is not always enough. If the line has behaved well, it can be deduced that it is safe; but it may also be too safe, that is to say, even if the strcutures were weakened the line might still operate satisfactorily and at the same time money would have been saved. It is difficult to know the extent of over-design of the lines in this case. All the weather conditions that may cause line faults can be examined only by the collection of measured actual values over a long period. In Finland, we have made observations concerning lightning, iceloads on the conductors, and freezing of the earth.

During the past three winters iceloads and hoar frost and their accumulation have been examined on a hill in northern Finland. This place was chosen because it is far to the north, and substantially higher than the lines on an average. The site is 230 m. above sea level, and a 400 kV line runs over it. From past experience it is known that iceloads and hoar frost are more easily developed at spots which are more than 200 m. above sea level. Studies are made at this

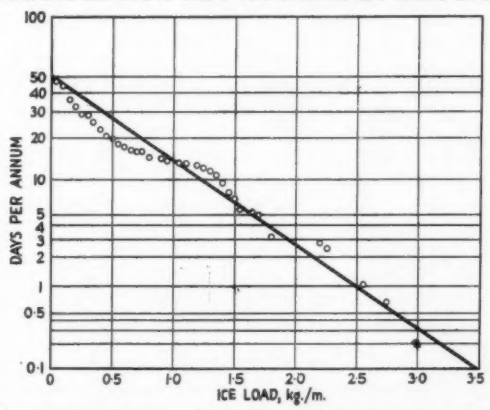


Fig. 1. Distribution of iceloads at Vammavaara observation station, 66° northern latitude. Ordinate shows the number of days annually during which the respective iceload was exceeded during 1956–1959

observation station on two test spans which are placed three metres above the ground, the low height having been chosen to facilitate the taking of samples and the carrying out of observations as exact as possible. The temperature and the humidity of the air are also measured, as well as the wind and the precipitation of rain. The maximum measured iceload during the three winters of observation was 2·75 kg. per m., and in Fig. 1 the distribution of the measured ice or hoar-frost loads is plotted on probability paper.

A general point about observations at this station can be noticed, that in this part of the country the loads accumulated on the conductors are not of ice but of hoar frost and snow. In no instance was hard and transparent ice detected on the conductors. In south Finland, in some few cases, real ice also has been noticed on conductors, but it seems that quite special weather conditions are needed for the formation of hard ice. Obviously the climate in Finland is favourable for the line designer, giving only moderate iceloads irrespective of the low temperatures.

In the Finnish safety code, an iceload of 2·5 kg. per m. is given for conductors which come into question for large transmission lines. We can see that this load is exceeded in the measurements. If only the strength of the conductors is considered, the danger of breakage can be estimated to be negligible. A line of 110 kV usually carries power that is sufficiently large to prevent ice from gathering on it. As far as higher voltages are concerned the conductors of a 400 kV line will touch the ground before they break, the corresponding iceload being 20 kg. per m. On the basis of the observations, the duration of the iceload in one successive period can be estimated at two days. Fig. 1 indicates that an iceload exceeding 2·5 kg. per m. occurs on an average one day a year. This means that the additional load which exceeds the value given in the safety code appears at this place once every two years. When designing towers for this site the assumed iceload was 5·0 kg. per m., or double the amount given in the safety code. All the vulnerable tower sites of this kind are considered separately, and the possible extra iceload is determined according to local conditions.

One factor which greatly affects the weight of the towers is the breakage of the conductor. In Finland, experience has shown that this occurrence is very rare on lines that can be designated as transmission lines. Nevertheless, this type of damage may happen for some external reason. If supports will not stand the impact caused by conductor breakage, so much dam-

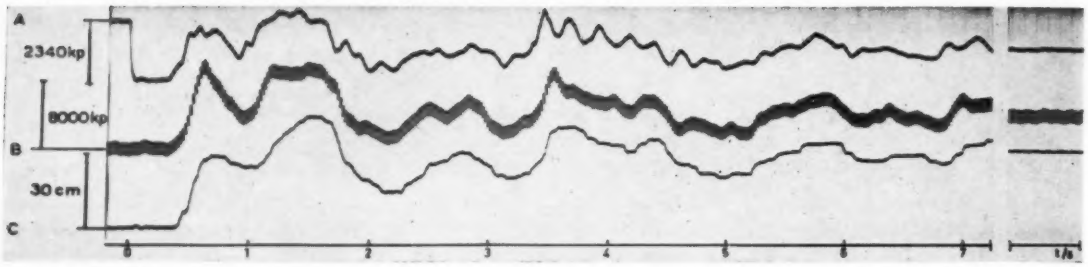


Fig. 2. Recording of a broken-conductor test. Curve A: force in conductor; curve B: force in guy; curve C: movement at the end of crossarm. Conditions: Guyed 220 kV steel tower (Fig. 5). Conductor: ACSR 455 sq. mm., insulator string 2·0 m. long

age can be caused to the line that the time of interruption will be very long. Though the risk of this kind of damage is very low, some standpoint must be assumed in the question of whether the towers must withstand the breakage of one or more conductors, or whether this is not necessary. On the other hand, the nature of the broken conductor force is dynamic. In designing the supports, static loads are usually applied, and so the magnitude of the assumed load is another question for consideration.

After making some tests on actual lines, a rule was adopted in the Finnish safety code which calculates the broken conductor force according to the following conditions:—

(1) The conductor breakage occurs when no additional load, either ice or wind, affects the conductors and the structures, the temperature being 0°C.

(2) The breakage imparts to the corresponding intact conductor of the adjacent span a force the magnitude of which is 40% of the tension in the conductor under iceload.

(3) Only one conductor or one subconductor of a bundle, but any one of them is assumed to break.

The iceload is adopted for this stipulation only as a convenient calculating rule which corresponds to the demands found necessary. The iceload is 2·5 kg. per m. without wind and at a temperature of 0°C. Fig. 2 is a reproduction of the force acting on the tower in one test, and gives the reader some idea of the duration and the magnitude of the force. The test was made on a 220 kV line, built with flexible guyed supports and steel-aluminium conductors. From other tests made with copper conductors, it was deduced that a rigid self-supporting tower is submitted to a broken-conductor force which is 50% more than that imposed on a flexible guyed structure.

For a period of short duration the steel can withstand greater stresses than under constant loading. By the aid of the studies made by Adamson[1] it can be estimated that in the case of Fig. 2 the yield strength of the steel is 25 kg. per sq. mm., the standard test value being 22 kg. per sq. mm.

All the forces discussed above are random variables of time, and that is why it is not justifiable from the point of view of economy to design structures to withstand maximum loads that can ever exist. This

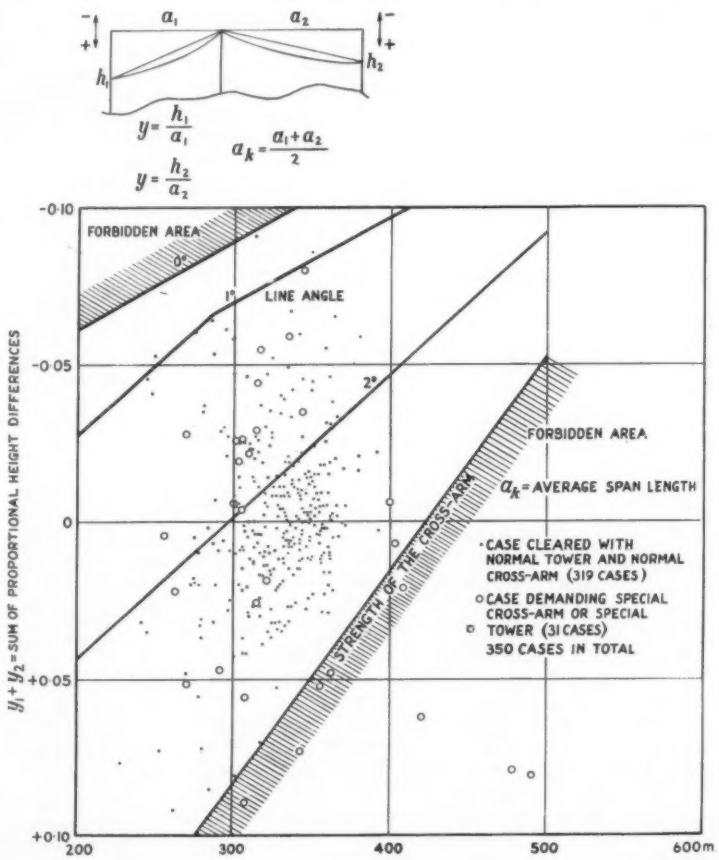


Fig. 3. Distribution of towers with line angle 2° or less on 400 kV line section Kangasala–Hyvinkää. Limits for use of normal tangent tower with normal crossarm are given for angles 0°, 1° and 2°

in turn leads to a consideration of the selection of the accepted risk of faults and interruptions. Actually, one must consider the possible number of faults that are linked to each alternative design. For instance, the breakage of the conductor on modern extra-high-voltage lines is a very rare occurrence. One exception in this respect is in the vicinity of large airfields, where in several cases aircraft have crashed against lines, but this kind of situation is not valid everywhere. As is shown above, large iceloads do not appear very often, and they certainly do not appear everywhere; furthermore, lightning, which is the major factor in fault statistics, also varies from year to year. The influence of lightning can be partly avoided by earthing, but under the conditions existing in Finland effective earthing is in general a very costly operation due to the high resistivity of the ground. Modern circuit-breaker technique with rapid auto-reclosing has proved to be very successful.

The experience of three years shows that in the Finnish 220 kV network 75% of faults are cleared without interruption. The corresponding figure in the 110 kV network is 50%, this low figure being due to entering branch-lines between stations and also to simpler apparatus. Because the 110 kV network is meshed, no better reclosing performance is necessary.

Fig. 4. Flexible guyed tower on Helsinki–Virkkala 110 kV line, built in 1930

The Most Economical Design of Line

In every country the opportunities afforded the line designer are limited by the safety code. For instance, there are stipulations that a tension tower must be put on the line at certain distances or that some kind of crossing must have tension towers on both sides of it. The conductor, as well as the spacing between phases, is usually determined by electrical considerations. Naturally in this respect there exists some feedback from the line designer to the system planner, because the size of the conductor and all the other electrical features of the line affect the structures, and thus also the cost of the line. The economical overall solution is naturally enough the optimum, where all the different factors are in balance. But experience has shown that the changes in the cost of the structures are such that in most cases the system planner can make his decision without knowledge of the towers. Nevertheless, when the conductors are being placed on the supports, there still remain some mechanical and mechanical-electrical considerations, and it is at this point that the above-mentioned safety features come into play.

If the conductors are in a horizontal configuration, possible reasons for earth faults are the conductor touching the earth wire or the support. The first-mentioned factor determines the ultimate height of the tower and the latter the length of the crossarm. In some countries, the possible dancing of conductors must be taken into account. This dancing refers to the vertical and horizontal movement of the conductors, usually brought about by simultaneous iceloads and wind. The spacing of the conductor and the earth wire must be such that the risk of touching is very little. In Finland, according to experience, this risk of dancing is very small, and so the ultimate height is usually sufficient only to prevent the iceloaded earth wire from touching the conductor under the influence of wind, the conductor being affected by wind but not by iceload.

The length of the crossarm is determined by the deflection of the insulator string. In Finland, two separate checkpoints are used. The first demand is that under extreme cold (– 40°C.), the distance from the live part to the tower must be at least 10% higher than the flashover distance of the insulator string. Secondly, in a wind (25 kg. per sq. m.) the permissible distance is 70% of the above-mentioned cold-weather value. The idea behind this consideration is that the risk of a simultaneous internal over-voltage and a strong wind is thought to be negligible.

The rules given above relating to the distance from live parts to the structures lead to a certain maximum

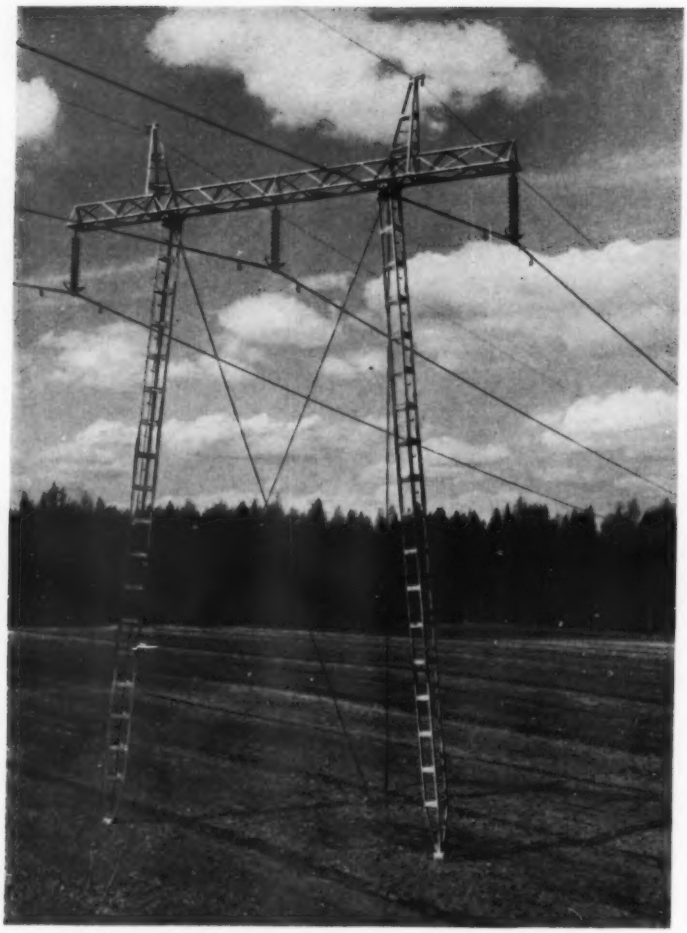


Fig. 5. Flexible guyed tower on Hikiä–Tammisto 220 kV line, built in 1954

allowable deflection angle. Each tower is then considered separately, according to curves which take into account the span length and the height differences of the support in question and the adjacent ones. When choosing the suitable allowable angle, experience from the past is made use of, in the form of statistics which give the distribution of different span lengths and height differences. Fig. 3 gives some idea of this procedure, as well as the normal conditions. This figure includes cases relating to the southern section of a 400 kV line under construction at the present moment. As one can see, the span length and the height differences are grouped rather closely, with a few exceptions. It is economical to design the normal tower to cover this large group, and not to take into consideration the few exceptions which can be dealt with separately.

The type of support itself is a subject for argument. If two circuits are needed and the route of the line is congested, double-circuit supports are no doubt the only possible solution. If the single-circuit type is adopted, the question still remains which kind of structure must be chosen. The most common single-circuit support used in the world nowadays is the self-supporting corset type. For thirty years the transmission lines in Finland have been equipped with flexible guyed towers, and Fig. 4 was the first design of this kind (from the year 1930). When one takes into account the need of material, as well as the working methods, the solution applied has in all comparisons of economy proved to be the best one. In recent years, the U.S.S.R. and Sweden have also adopted the same type of support for 220 kV and 400 kV lines. Some people have misgivings about the guys and the flexibility of the supports, and some complain that this type of tower occupies considerably more land than the conventional self-supporting structure. From experience we know in Finland that no extra danger is associated with the use of guys, and the guyed support occupies very little more area than any other type. Fig. 5 shows clearly how little annoyance has been caused for a farmer by a 220 kV guyed support.

The Design of a 400 kV Line

As an example of the principles given above, the features of one 400 kV line in Finland are given. This job will be completed in 1960, and by then a 758 km. long 400 kV line from the north to the south of Finland will be put into service at full voltage.

Fig. 6 gives the main dimensions of the normal tangent support, and Table IV contains the technical data of the line. The concrete footings and the guy anchors are fabricated on sites close to the right-of-way. The concrete blocks are transported to site mainly in wintertime by trucks and tractors. By reason of the sparse road network, and the many soft spots in the terrain, winter transport is the right way to treat this problem because

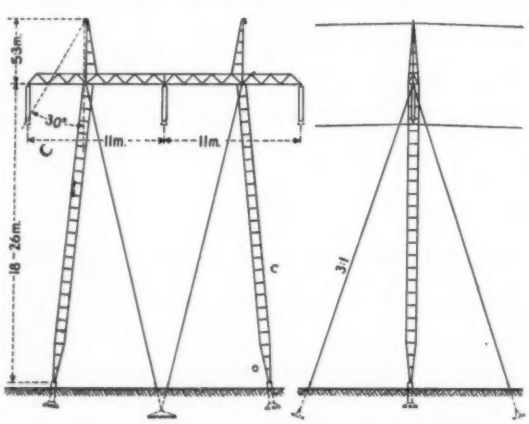


Fig. 6. Flexible guyed tower on Alajärvi–Hyvinkää 400 kV line; will be completed in 1960

Fig. 7. Transport of footings for a 400 kV line

temporary roads are cheaper to make and to maintain in winter than they are in summer.

The tower has been constructed by welding. The legs consist of three parts, the crossarm of two parts, and the extensions for the earth wires are also separate. All the parts are transported to site by trucks, and assembly is carried out there by bolting the towers together on the ground. A second crew erects the supports by the aid of a tractor, and a third and larger group installs the insulator strings, the conductors and all accessories, including the spacers between the subconductors.

In the paragraphs below we have set out some "why's" which can be put concerning the selection of

TABLE IV.—DATA FOR THE ALAJÄRVI-HYVINKÄÄ 400 kV LINE

Length of line	295 km.
Insulation level—	
$1\frac{1}{2} \times 40$ μ's impulse, 50% value	1450 kV
50 cycle, wet flashover	705 kV
Insulators—	
18 units, cap and pin, $10'' \times 5\frac{3}{4}''$ electro-mechanical strength ...	11·3 tons
Conductors ACSR Finch—	
Number per phase	2
Spacing of subconductors ...	450 mm.
Stress at +15°C., without additional load	5·4 kg. per sq. mm.
Same in percentage of breaking strength	19%
Earth wires, steel cable, area ...	68 sq. mm.
Stress at +5°C., without additional load	14·8 kg. per sq. mm.
Same in percentage of breaking strength	11%
Average span	324 m.
Longest span	634 m.
Amount of steel in tower ...	12·9 tons per km.
Amount of concrete	9·8 cu. m. per km.
Amount of steel reinforcement ...	0·7 tons per km.
Steel used in towers—	
Mild steel, yield stress minimum	22 kg. per sq. mm.
Safety factors with regard to yield stress—	
Condition (a)	1·40
Condition (b)	1·40
Condition (c)	1·15
Loadings—	
(a) Wind condition:	
Conductors	25 kg. per sq. m.
Structures	100 kg. per sq. m.
(Both against projected total area)	
Temperature	−20°C.
No ice	
(b) Iceload:	
Iceload on conductors and earth wires	2·5 kg. per m.
Temperature	0°C.
No wind	
No iceload on structures ...	
(c) Broken wire:	
Longitudinal force at any suspension point of the conductor	2655 kg.
(40% of the conductor tension in condition (b))	
At any suspension point of the earth wire	1445 kg.
(40% of the earth-wire tension in condition (b))	
Temperature	0°C.
No wind	
No iceload	
Only one conductor or earth wire is assumed as breaking	

Fig. 8. Installation of insulator accessories

dimensions and other features on the line.

Span Length. The most economical span length proved to be between 350 and 400 m., but the difference is very small when working on this range. To avoid the hazards associated with unexpectedly large iceloads it was decided to use a ruling span of 350 m., but when the prepared charts were applied to the actual terrain, it was found that the average span on the line was only 324 m., which was accepted.

Permitted Deflection Angle of the Insulator String. As is shown in Fig. 3, the normal tangent tower (and normal crossarm) does not cover all the cases that would be possible with regard to the forces acting on the tower; but most of the cases are covered by the normal support, and those few which are beyond the limits will be treated partly by the aid of a structure of the same type with a different crossarm, and partly by the aid of special towers.

Insulation Level. The insulator string of a normal tangent tower has 18 units of conventional type 10 in. × 5¾ in., and at the bottom end of the string arcing horns are installed. The withstand impulse voltage of the transformers is 1,650 kV and the wet withstand voltage at power frequency 725 kV. In future, the insulation level of new transformers will be only 1,400 or 1,500 kV. In this light, it was sensible to set the impulse flashover level of the line at 1,450 kV (50% value). At the same time, it was noted that this kind of insulator string has a wet power-frequency flashover voltage of 705 kV. The maximum service voltage of the line will be 420 kV, which corresponds to a voltage of 243 kV over the insulator string. The ratio of the wet flashover voltage of the chain compared with the maximum service voltage is 2·9, which is considered quite sufficient as regards possible internal overvoltages. In the older part of the 400 kV network, the insulator string was longer, the 50% impulse flashover voltage being 1,620 kV. When this insulation level was compared with the reduced one, it was found that the expected difference in lightning fault levels was negligible. A shortened insulator string makes the work of the tower designer easier, also showing the way to a reduced insulation level.

Lightning Fault Level and Earthing of the Towers. In general, the resistivity of the earth in Finland is so high that for the majority of the supports one can get a footing resistance of 25 ohms or less at a moderate cost. When doing so, the expected fault-level difference is about 0·5 faults per 100 km. per annum, when comparison is made with the line with no extra earthing. The cost of the earthing is £34 per km., which means that the elimination of one lightning fault costs £680 (annual capital and maintenance cost 10%). This expenditure has been thought to be reasonable.

Conclusions

An examination shows that the towers are the point where the line designer can most substantially alter the cost of the line, but in many cases, the safety code sets limits for him. Therefore the stipulations, and in particular those which give the values of the loads, must correspond with reality. In those cases where possible damage to the line will probably not occasion any danger or harm to outside agencies, a certain risk can be accepted. There is no economic justification for building the line sufficiently strong to withstand even the maximum loadings possible. As in all fields of technique, the possibility of reducing the cost of the structures lies mainly in improved knowledge of the forces encountered and the material used. General development has thus shown the way to reduce the safety factor against any hazards. This is also the way along which the line designer must proceed, but consequently the safety codes must also follow the development of techniques, and not impose restrictions that are too heavy, loads that are too big and safety factors that are too exacting, as barriers to the line designer.

REFERENCES

[1] ADAMSON, B.: "Influence of Fast Loadings and Low Temperatures on the Strength Properties of Steel." *Tekniska Skrifter*, nr. 146 (1950), Swedish.

[2] HARO, MAGNUSSON, PÖNNI: "Investigation on Forces Acting on a Support after Conductor Breakage." CIGRE Report 210/1956.

[3] HARO, MAGNUSSON: "Economic Aspects of the Construction of the High-Voltage Transmission Lines in Finland." World Power Conference Paper 101 D/3, 1958.

Henderson Derrick Cranes. John M. Henderson & Co. Ltd., King's Works, Aberdeen, have published a four-colour brochure dealing with their well-known derrick cranes, which are fully described.

Heavy-Duty Insulators for High Voltages. Doulton Industrial Porcelains Limited, Doulton House, Albert Embankment, London, S.E.1, have extended their range of post insulators to include a 275 kV working voltage insulator. Satisfactory tests were conducted in the presence of engineers of the Central Electricity Generating Board, who gave their approval. A copy of the report of the tests is available to those especially interested. This present advance of the company makes them able to quote against requirements for working voltages of up to 330 kV.

Underwater Blasting and Blasting through Overburden

An account is given of some of the most important findings which have resulted from investigations made in Sweden involving the blasting of rock surfaces below water or under relatively loose soil deposits

By ULF LANGEFORS

PART TWO

IT is desired, if possible, to blast an entire shoulder of rock in one round, or at any rate take as large sections of it as possible. In many cases it takes one or two weeks to charge the round. The explosive must be so selected that it is not damaged by water so that it will detonate with its full breaking capacity. Table VII gives for some different explosives the number of days which a cartridge of 25 mm. diameter can be suspended in water before its flashover capacity = 0. Blasting gelatine, which is given in the last column, can lie in water for an almost unlimited time without being destroyed. This is hardly desirable for ordinary underwater blasting. For LFB, a Swedish dynamite with 35% nitroglycerine, the upsetting test value after 2 days diminished from 25 to 23, after 4 days to 21 and after 7 days to 0. This may give some idea of how the strength decreases.

For a charge which is tightly rammed into a drill hole the time will be considerably longer as the surface exposed to the water is comparatively small and still water soon becomes saturated with the salts of the explosive which are soluble in water. When keeping them there longer it may be advisable to place the electric detonator in a cartridge of LF60 (60% ngl.) even if the rest of the drill hole should be charged with LFB or LF45 (45% ngl.). Rounds with LFB blasted three weeks after charging have detonated satisfactorily, provided, however, that the water had not been able to flow through cracks and crevices. Blasting gelatine has usually been used, but LF45 and LF60 are more suitable in most cases, and sometimes LFB. For reasons of safety it is preferable to have an explosive that is destroyed after a certain time.

Another point of view which has not been taken into consideration hitherto is that blasting gelatine entails great risks of a flashover between different holes. One of the most important measures from the point of view of safety should be to prevent the spreading of such unintentional ignition of the charge from an individual hole to other holes in the round. Table VIII gives a comparison between the various kinds of dynamite. The values have been received for two parallel 25 mm cartridges of the same explosive suspended in water. When charged with a loader, holes of 30 mm. diameter achieve a high detonation velocity.

In full-scale tests occasional cases of flashover have been obtained with 3 kg. per m. at a distance of 2 m. between the holes. Some further values are given in Fig. 8 in which a curve has been drawn according to the law of conformity. It will be seen on comparison with Fig. 2 that burden V_1 for $d = 50$ and $l = 2{\cdot}5$ kg. per m. is already near the limit for a flashover between the holes (about 1·8 m.). If V_1 is corrected to lower values the risk of a flashover increases. This implies that at present it appears to be difficult to carry out underwater blasting entirely without risk of flashover.

To improve the conditions only alternate holes need be charged in a first operation so that during this part of the job the distance in all directions to the nearest hole is about $\sqrt{2}V_1$. There is little probability of a flashover occurring here. In this way more than half the charging time has passed when the turn comes for the second part of the charging. In unbroken rock there can be no flashover; Fig. 8 applies to flashover in water, i.e., if there are big crevices between the holes. When this is the case the water helps to reduce the sensitivity to flashover. The risk of flashover in the event of unintentional ignition is consequently diminished by charging alternate holes during the first half of the charging operation, as well as during the second and the subsequent blasting of the rock. In deep-water blasting when the explosive must lie a long time under high pressure a special explosive is needed.

Charging of Holes

Nitroglycerin A.B.'s pneumatic loaders [3, 4, 5] are used for charging. Further details are contained in the

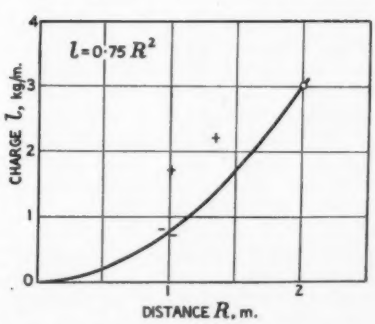


Fig. 8. Relation between weight of charge per metre and flashover distance in water. + indicates flashover, 0 limit, − no flashover. Inserted curve indicates charges which do not give flashovers at distances less than 2 m.

Fig. 9. Loading with pneumatic tube loader in underwater rounds. (a) Explosive inserted in tube through the breech. (b) Loader works with water pressure (3 atm.) connected from the upper level when charge required for one hole has been inserted in the tube. Loading done by diver. At the upper level the manometer indicates when the hole is fully loaded. (c) and (d) Round is under a layer of clay which has not been removed

Nitroglycerin Company's directions for these loaders. They play such a decisive part in rational underwater blasting that after having tried out this loading method there is no reason to mention any other type. The job is done rapidly and smoothly with a high degree of compaction and less risk of the holes becoming choked and the detonators damaged.

There are two types of the loader, *S* and *R*, the one with a continuous polythene tube, the other with jointed 1·6 m. metal tubes. There are two sizes of each, adapted for 22 and 25 mm. cartridges respectively. With the polythene loader the diameters of the drill hole at the bottom must be at least 37 and 40 mm. respectively. The values for the metal-tube loader are 30 and 33 mm. As the polythene loader offers many advantages a larger diameter of hole than 40 mm. should be selected in underwater blasting. There is no need for jointing, as in the metal-tube loader; there is less strain on the electric detonators, their wires and

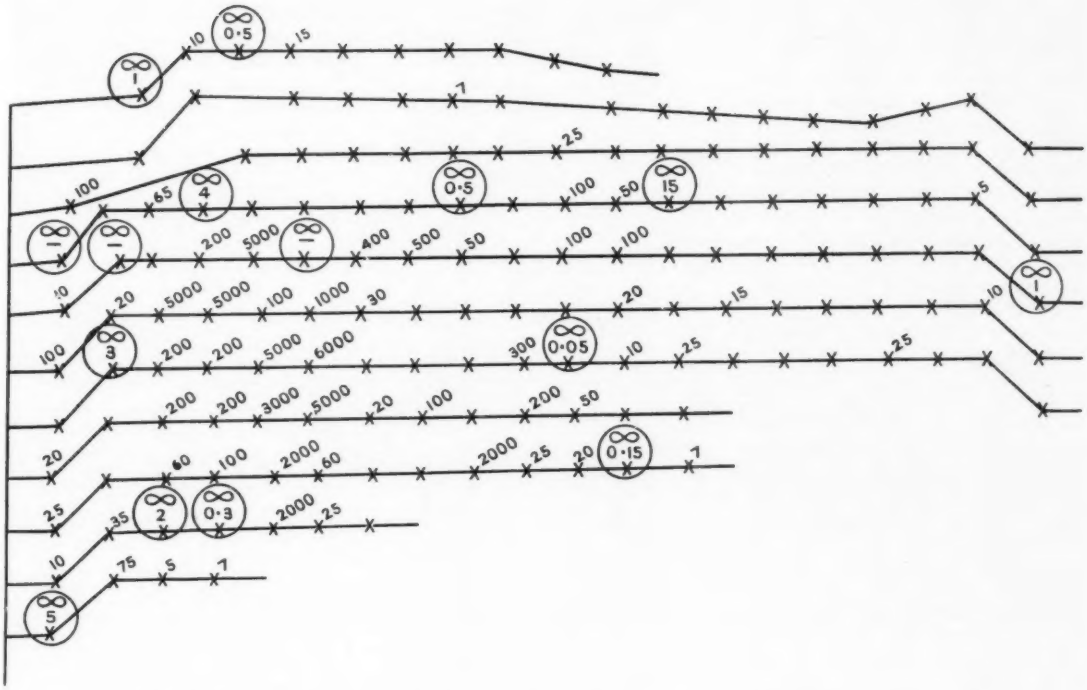


Fig. 10. Result of insulation measurement for a round with depth of hole between 1 and 9·6 m. The resistance has been infinity where no figures are indicated

insulation. Bännmark[6] states that the percentage of damaged detonators in the work at Stenungsund and Lindö was 20% with the metal loader, but only 7·5% for the polythene one. He reports that some of the polythene loaders had been used for loading up to 8 tons each and were still satisfactory.

A development which has further increased the efficiency of the loader is the fact that power water can be used as a driving medium instead of compressed air. The loader is inserted in the hole either by a diver, or, if possible, direct from the working level above the water. A compacting effect giving a charge quantity of 2·5–3·0 kg. per m. in a 50 mm. hole is achieved.

Fig. 9a–d shows some examples of the use of the pneumatic loader. The charging is done by two men. The explosive is inserted in the loader by one man, as in Fig. 9a, and by the man on the left in Fig. 9c. In Figs. 9a and b the other is not visible because he is a diver who inserts the loader and detonator in the drill hole and afterwards carries out the rest of the charging. In the instances illustrated in a and b water pressure has been employed. While the diver is at work the man at the upper level has only to check the pressure in the apparatus on a manometer, and when the apparatus has been emptied the pressure falls from 3 atm. to a level corresponding to the depth of the water. The loader must then be refilled—in the case in question—with just as much explosive as is intended for the next drill hole.

In Figs. 9c and d the division of labour is similar for a round which is drilled and blasted without removing the overburden. The work which was done in the earlier instance by a diver is now done by the man on the right in Fig. 9c. He is apparently comfortably seated on a box, but it is actually possible for him to apply great power with the grip, and since he is practically sitting above the hole he does not get the spurting water and explosive particles from the hole in his face. Otherwise the person who does the charging usually stands as in Fig. 9d.

In charging it is important to see that only the intended quantity of explosive is inserted in the drill hole. If we allow for 2·5–3·0 kg. per m. this quantity should not be appreciably exceeded. In certain cases this may happen if the loader presses out the explosive into large crevices and fissures in the rock. If this occurs it is impossible to avoid a flashover to contiguous holes and consequently risk an unsatisfactory break at the bottom.

When using pneumatic loaders it will easily be noticed if there is any crevice connecting the hole being charged with adjacent ones. A note of this should be made and marked on the drilling pattern. The holes affected should be charged with an explosive which is less sensitive to a flashover.

Electric Ignition and Control

Ordinary electric detonators can nowadays stand exposure to such water pressure as occurs in underwater blasting. For deep-water blasting at a greater

TABLE VII.—NUMBER OF DAYS FOR EXPLOSIVE TO DETERIORATE UNDER WATER

Explosive	LFB	LFIV	LF60	BG
Number of days until flashover capacity = 0 ...	2	7	21	more than 360
Breaking capacity *s* ...	1·0	1·07	1·15	1·27

depth than 20 m. special detonators are needed. If possible, the electric wires should have extra-strong insulation. A common cause of faults is that the insulation is damaged when charging. There should be no joints below the surface of the water. Should such joints have to be made they must be insulated by dipping in plastic of the type which is now being used to protect tools kept in storage against corrosion (hot-metal plastic). It must be plastic without oil, for example, cellulose acetobutyrate, which is heated to 160–180°C.

Every charge should be provided with two or more electric detonators, especially if they cannot be easily placed there after something has gone wrong with the first one. The wires from each detonator should be drawn up separately above the surface of the water. When the demand for certain ignition is especially great the detonators can be connected up in the same drill hole to different series.

Short-delay blasting caps are used. Ignition patterns are made up in suitable parts and the blasting is carried out in keeping with instructions which apply to short-delay blasting[2].

Underwater rounds make heavy demands on the ignition machine, which must be ample for a larger number of detonators. This implies condenser-igniting machines of 500–2,000 V, or a short-delay apparatus of 350 V[7]. The ignition system is checked not only with an ordinary resistance meter (e.g. type G Norma), but also with a so-called earth-fault tester; and when blasting in salt water it is usual to have an instrument for testing the insulation as well. This last-mentioned instrument must only be connected up from a safe spot. This means that the measurement takes time, and even if the blasting site has been evacuated the risk of involuntary ignition is a handicap which makes the instrument less attractive.

The earth-fault tester has been constructed by Enoksson[8] and is based on the principle that the explosive, subsoil water and such like in contact with a metallic conductor form a galvanic element which can generate a very weak, but measurable electric current. This can be determined with a sufficiently sensitive instrument (μA meter). The measuring should be carried out when the electric detonator is being pushed down the hole, or as soon as possible after the charging, because after some time the instrument may record complete deflection even if the insulation resistance is great enough. In so doing the detonator, or a series of detonators, is connected to the one pole of the instrument, while the other pole is appropriately earthed.

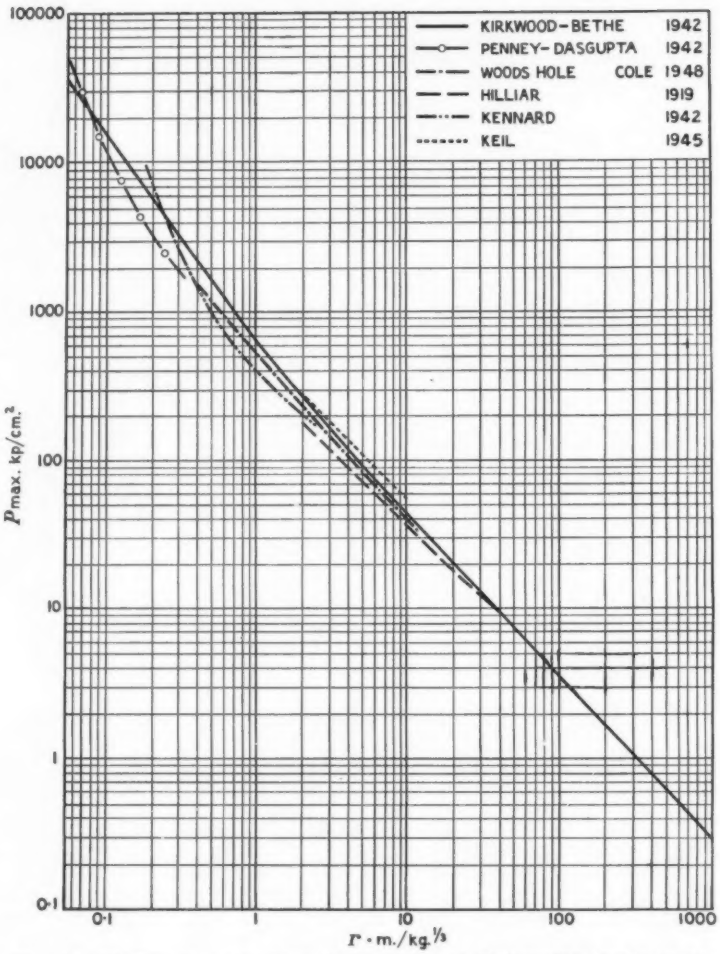


Fig. 11. Maximum pressure p *from a charge* Q *hanging freely in the water at distance* $R = rQ^{\frac{1}{3}}$ *(according to Enhamre[11])*

The earth pole must not be connected to any object, such as rails and pipelines, which can transmit power current.

A calculation by N. Lundborg shows that the earth resistance for every series should be at least twice the resistance of the series itself. In the case of underwater rounds that have been examined, a large number of the detonators have had an insulation resistance between 5–100 kΩ. Ordinary insulation testers cannot be employed under 100 kΩ. The measurements have been carried out with a special instrument according to Lundborg and Kihlström[9] with 500 V open-circuit voltage.

Fig. 10 shows a connecting schedule for an underwater round with 162 holes. The insulation resistance

TABLE VIII.—DISTANCE IN CM. FOR A FLASHOVER/NON FLASHOVER AT A HIGH AND A LOW VELOCITY OF DETONATION IN THE PRIMARY CHARGE

Detonation velocity in the primary charge	Dynamite with a percentage of ngl. of			
	35	45	60	97
High	60/65	65/70	65/70	85/90
Low	45/50	50/55	60/65	—

has been measured and indicated hole by hole with the detonating caps in every hole. In cases where the resistance is lower than 5 kΩ the detonating cap is disconnected and a new one substituted, the insulation resistance of which is indicated above the original one. For the holes which have had infinite insulation resistance from the beginning no numeral is given in the figure.

In order to reduce the risk of incomplete ignition as a result of earth faults it is advisable to limit the number of detonating caps per series so that the serial resistance is kept low, e.g. at 125 ohm. With large rounds the number of parallel series will be large and require a thick ignition cable.

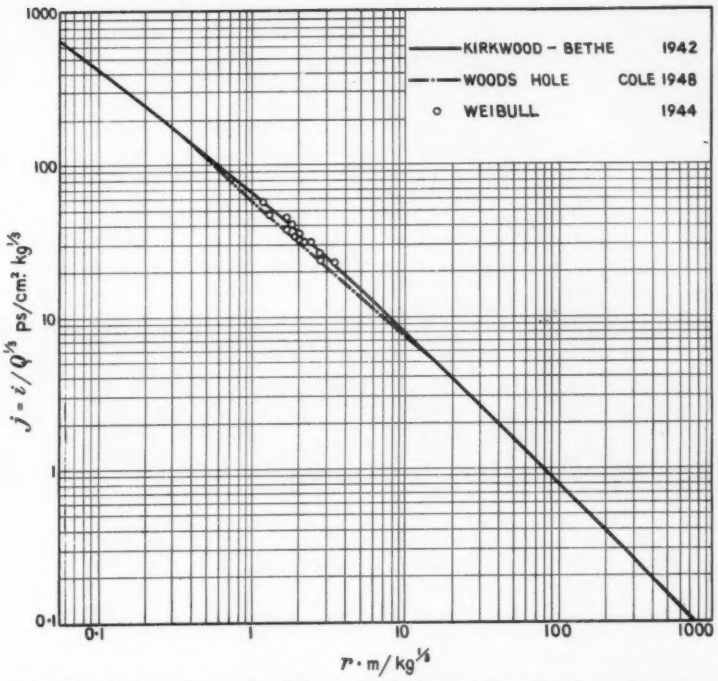


Fig. 12. Reduced impulse j *for calculation of impulse* $i = jQ^{\frac{1}{3}}$ *from a charge handing freely in water (according to Enhamre[11])*

Ground Vibrations and Water Shock Waves

General bases for dealing with problems in connection with the ground vibrations are given in Ref. 10. The characterisation of underwater rounds as opposed to ordinary blasting is, first, the risk of a flashover and, second, the larger quantity of charge. This makes estimates not only more complicated but also more uncertain since there is no assurance how a flashover will occur. Apart from the fact that a flashover causes a greater total charge to be ignited within a certain time, e.g. between 2 intervals (30 ms.), there is the fact that faulty ignition sequence causes greater fixation and consequently stronger ground vibrations.

When the round is very extended differences in time must be counted on owing to the distance between the charges besides that due to the short-interval detonators. This effect is most simply illustrated in the blasting of a whole round with instantaneous blasting caps, i.e. the interval time $\tau = 0$. If the distance to the drill holes from a measuring place for registration of the ground waves is 90–150 m., there will be a difference in the time of arrival corresponding to 60 m. between the ground wave from the nearest holes and those which are farthest away. In time this implies 20 ms. if the ground wave travels with a velocity of 3000 m. per sec. The ground vibrations are thus affected so that the highest frequencies are practically eliminated through interference, whereas the lowest remain comparatively unchanged.

In the examples given oscillations which have a half

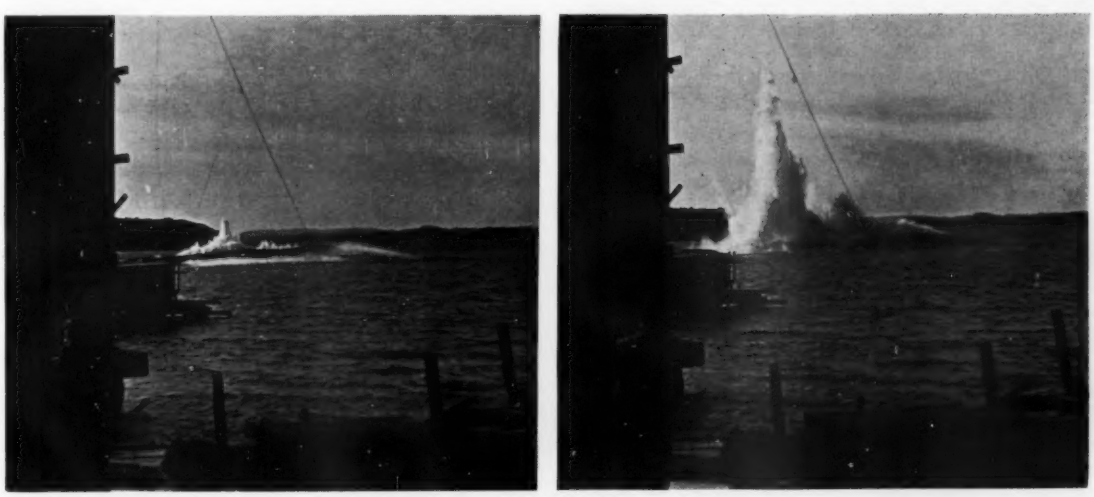


Fig. 13. Blasting of round in Fig. 14

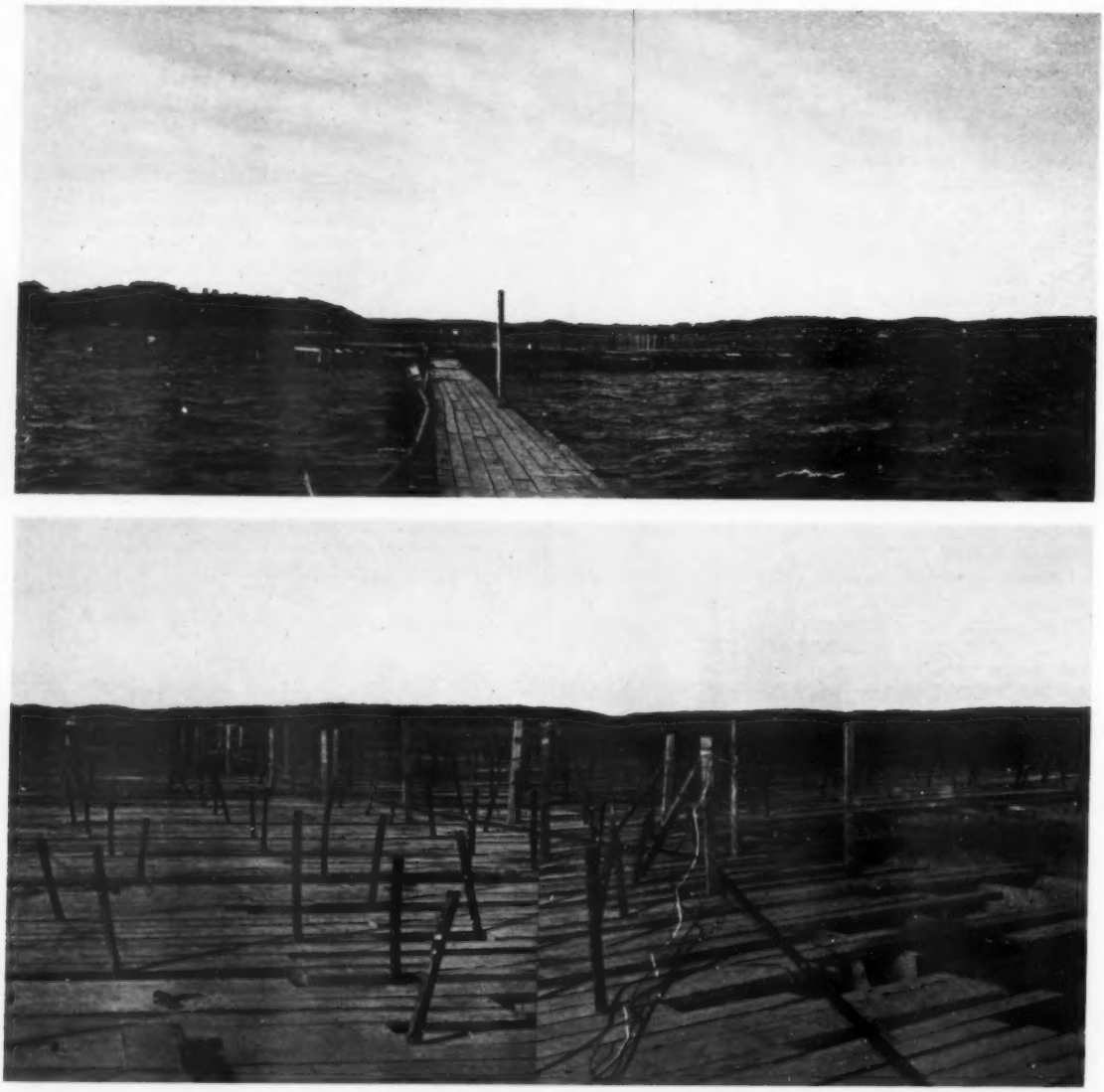


Fig. 14. Working platform for blasting underwater round in open water. The plastic tubes which "extend" its drill holes up above the water surface are seen in the lower picture (AB Skånska Cementgjuteriet)

period $T/2 = 20$ ms. are not appreciably reduced. For the double frequency $f = 50$ periods per sec. and higher values, on the contrary, there can be a reduction to 1/10 compared with that if all the charges co-operated. As the highest frequencies also give the greatest stresses in the rock this implies that the distance-interference in the case of widely extended rounds is of great practical significance.

If the rock is covered with large layers of earth, clay or such like which extend into the surroundings, and there comprise the foundation for dwelling houses, conditions will be different since the waves which then have the greatest damaging effect have low frequencies, $f = 10$ periods per sec., or lower. Ordinarily the distance-interference is then of no importance. Reduction of the low-frequency oscillations here is achieved exclusively with the aid of delay ignition.

Another problem which is sometimes met with in underwater blasting is the effect of shock waves in the water on intakes, dam gates and other constructional details near the blasting site. For spherical charges suspended freely in the water questions falling under this category have been dealt with by E. Enhamre[11]. For such cases Fig. 11 gives the connection between the maximum pressure p_{max} of the water shock wave and the reduced radius r (m. per kg.$^{\frac{1}{3}}$). With charge $Q = 1$ kg. the reduced radius is the distance R to the charge. If Q is larger than unity, r is obtained from the relation

$$r = R/Q^{\frac{1}{3}}$$

The duration of the water shock wave is so short that it has dropped to half the pressure in the fraction of a millisecond after the peak value. This implies

in practice that co-operation does not occur between charges which are ignited at different intervals when the difference in time amounts to 12–50 ms., nor even for different charges which are ignited with the same interval in which the relative scatter is of the magnitude between $\pm$ 5 ms., and $\pm$ 20 ms. In ignition without a flashover a maximum pressure of the same order of magnitude as from individual holes can be counted on.

If there is a flashover the "interval time" is equal to that for the pressure wave to be transmitted in water from one hole to the next. This time is of the order of magnitude of 1 ms. If such flashovers affect a large section of the round, co-operation of the water shock waves can be obtained between several different holes.

It remains to estimate how great a reduction in the maximum pressure can be counted on compared with the values according to Fig. 11, since the charges in underwater blasting are placed in solid rock and only a limited portion of the shock wave energy is transmitted to the water. Without entering into a discussion of details it will merely be mentioned here that it would seem to be sufficient to count on one-tenth of the actual charge per hole. A round which is ignited with short delays, and in which the charges per hole are 10 kg., can consequently be expected to give a maximum pressure in water corresponding to $Q = 1$ kg. in Fig. 11. At a distance of 10 m. we have then $p_{max} = 40$–60 kg. per sq. cm., at 20 m. $p_{max} = 20$ kg. per sq. cm., etc.

If excessive maximum pressures are feared the structures affected may be screened off by an air shutter. This reduces the top values in the pressure-time curve. On the other hand there is no reduction in the incoming impulse as the law of the constancy of the impulse is not nullified by an air shutter. If there is a risk that the impulse values will be too high they can be reduced either by a cribbing which transmits the impulse from, say, a particularly sensitive inlet door to adjacent, less-sensitive elements, or the door can be loaded from behind with water pressure or a mechanical support to which part of the impulse will be transmitted. Fig. 12 gives, according to Enhamre[11], the reduced impulse density $j = i/Q^{\frac{1}{3}}$, as a function of the reduced radius where i is the impulse density. For $Q = 1$, $j = i$ and given in kg. sec. per sq. cm. and r in metres. If Q is greater, the recorded j values should be multiplied by $Q^{\frac{1}{3}}$ so as to give the impulse density i.

Various Types of Objects

Underwater blasting covers a very wide range of objects with most varying conditions. This is perhaps best illustrated by the fact that, apart from blasting small and ordinary rounds, the world's largest blast with over 1 Mkg. in a round must also be included in this group. Then there are in addition the external circumstances, which vary considerably, and the fact that in working in open waters one is at the mercy of the weather and the vagaries of nature to an extent practically unknown in ordinary bench blasting.

It is characteristic of all general planning of the work that endeavours are made to reduce or eliminate work with divers. A platform is built from which the work can be carried out, as will be seen from Fig. 14. If a platform is used which can be transported to the spot with the help of pontoons or such like, it should be firmly anchored to the bottom, and to avoid the effects of a swell the pontoons should be placed beneath the surface of the sea if they are to have a bearing function. Work from a raft in open waters entails great difficulties, not least in drilling. Then again the drill holes have to be driven vertically, which is a disadvantage from the viewpoint of blasting technique.

Fig. 13 shows the movement and rise of the water when blasting a round of 5 tons. One photograph was taken some tenths of a second after ignition, the other after some seconds.

The problems with a working platform are eliminated if the ice-cover of the water can be used for drilling and charging. It must not be forgotten, on the other hand, that variations in the level of the water

Fig. 15. Checking of ignition system in underwater round drilled from ice-covered water surface (AB Skånska Cementgjuteriet)

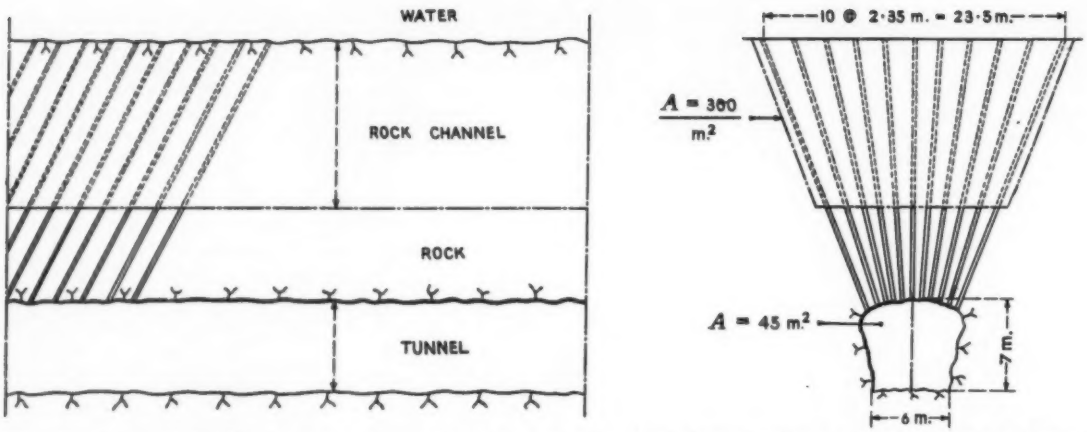


Fig. 16. Proposal for blasting rock channel under water. Work carried out from a working tunnel blasted out beneath intended channel. ═══ drill hole loaded with explosive. ═══ injected cement. Hole diameter 50 mm. Channel to be blasted to depth of about 50 m. below water surface

which alter the level of the ice crust may hazard the entire round if the extension tubes of the drill holes are withdrawn. Fig. 15 shows a fine example of a well-organised plan for underwater blasting from ice.

Another possibility of avoiding many of the practical difficulties entailed in deep underwater blasting is illustrated in Fig. 16*. This applies to a channel which is to be blasted in underwater rock to a depth of about 50 m. With a working tunnel under the channel, as will be seen from the figure, the drilling and blasting for the channel can be done as in simple stoping. The problems to be solved here are rendering the drill holes and joints between two consecutive rounds leakproof if the drilling is done in advance. Here too, as is usually the case with underwater rounds, it will be desirable to blast as large rounds as possible.

Fig. 17 shows a round of 15 tons which is blasted under an overburden of clay and earth. The photo-

* The method, which is based on a proposal by the Nitroglycerin Company in 1957, has a number of features in common with the so-called Janol method, but it should be pointed out that the latter was evolved without a knowledge of the former.

Fig. 17. A phase in a round of 15 tons and 800 holes blasted without removing layer of clay (AB Skånska Cementgjuteriet). Picture taken 1,000 ms. (1 sec.) after the ignition of the round

graph was taken 1000 ms. after the current was switched on. A more detailed account of this and the previous type of blasting is given by Brännfors[12].

Practical Directions

As a result of investigations which have been made the following general directions can be given:—

(1) The aim should be to have the smallest possible number of holes that will give a full guarantee for breakage and satisfactory fragmentation.

(2) This implies, among other things, that large drill holes should be used.

(3) The holes should be arranged in a very simple pattern, even if some additional ones are needed at occasional points in the round.

(4) It is essential to avoid a flashover between the holes. A flashover causes inferior fragmentation and risk of incomplete loosening of the rock at the bottom. This implies that the result can be impaired by increasing the quantity of the charge in a round. Moreover, the charge must not rise too close to the top face of the rock. At least a length $= V/2$ should be left uncharged (possibly less, however, with a greatly reduced charge per metre).

(5) The risk of a flashover can be reduced by charging every alternate hole with an explosive which is less sensitive to a flashover.

(6) Sloping drill holes give a better guarantee for bottom breakage and, at small bench heights, a considerably reduced number of holes.

(7) By blasting 1 to 2 m. below the bottom at low bench heights a considerable reduction in the number of holes is obtained. The drill holes should be driven at least 0·6 of the maximum burden under the intended bottom.

(8) Charging should be done with the Nitroglycerin Company's pneumatic or water-pressure loader.

(9) Only alternate holes should be charged in the first relay.

(10) Every hole should be provided with two or more electric igniters.

(11) Increased inspection of the ignition system is needed. Every detonator should be tested directly with an earth-fault tester in the course of charging, as well as before being finally connected to the round.

(12) When connecting up large rounds with two bottom detonators per hole in different series it is advisable to do this in teams of two men. Then the one man will advance slightly before the other and connect the one series, marking it, for instance, with yellow plastic sheaths over the joints; the second connecting the remaining detonators marks the joints, for instance, with black sheaths.

(13) The explosive should be able to stand storage in water for the time required, but not for an indefinite period.

(14) In many instances work by a diver under water can be avoided by constructing special drilling platforms and polythene tubes which will extend the holes to above the surface of the water, by drilling from the ice-covered surface if there is a possibility to do the work during the winter, or, when blasting a channel at a greater depth, by working from a smaller tunnel which has been driven in solid rock, under the channel intended.

(15) A rock face which has a cover of material other than water need not be laid bare in order to achieve free breakage in blasting.

(16) In dealing with the problem of ground vibrations special attention must be devoted to the risk of changes in the ignition sequence and fixation conditions, if the possibility of a flashover between different rows of the round must be taken into account. For large and scattered rounds regard must be had both to reduction by the delay ignition and by the difference in running times for waves coming from different parts of the round.

REFERENCES

1 LANGEFORS, U. "Calculation of Charges in Rock Blasting" (in Swedish: "Laddningsberäkning vid sprängning") TM 1 Nitroglycerin AB, Gyttorp, Sweden (1953).
"The Calculating of Charges for Bench Blasting and Stoping", *Manual on Rock Blasting* 6 : 05, Atlas Copco and Sandvikens Jernverk, Stockholm (1954).

2 LANGEFORS, U. "Short-Delay Blasting", *Manual on Rock Blasting* 16 : 11, Atlas Copco and Sandvikens Jernverk, Stockholm (1952).

3 JOHANSSON, C. H. "Charging of Drill Holes." *Mine and Quarry Eng.* 21 (1955), *Canadian Mining Journal* 76 (1955).

4 JOHANSSON, C. H. "The Development of the Pneumatic Loader" (in Swedish: "Den tryckluftdrivna laddapparatens utveckling"). Bergsprängningskommittén Örebro-Gyttorp, Stockholm (1957), p. 120.

5 LJUNGBERG, S. "Charging of Drill Holes" (in Swedish: "Laddning av borrhål"), Bergsprängning, FKO-meddelande nr 30, IVA, Stockholm (1959), p. 87.

6 BÄNNMARK, O. "Contribution to the Discussion on the Pneumatic Loader." Bergsprängningskommittén Örebro-Gyttorp, Stockholm, (1957), p. 128.

7 JOHANSSON, C. H. "Firing Electrically", *Manual on Rock Blasting* 16 : 10, Atlas Copco and Sandvikens Jernverk, Stockholm (1952).

7a JOHANSSON, C. H., LUNDBORG, N. "Firing Electrically", *Manual on Rock Blasting* 16 : 10, Atlas Copco and Sandvikens Jernverk, Stockholm (1958).

8 ENOKSSON, B. "Investigations on Measurements of Earth Faults" (in Swedish: "Undersökningar över jordfelsbestämningar"). Bergsprängningskommittén Örebro-Gyttorp, Stockholm, 1957, p. 102.

9 KIHLSTRÖM, B. "Measuring the Insulation in an Underwater Round" (in Swedish: "Isolationsmätning på en u-salva"), Bergsprängningskommittén, Örebro-Gyttorp, Stockholm 1957), p. 107.

10 LANGEFORS, U., WESTERBERG, H., KIHLSTRÖM, B. "Ground Vibrations in Blasting", WATER POWER, London, 10 (1958), pp. 335–338, 390–395, 421–424.

11 ENHAMRE, E. "Effects of Underwater Explosions on Elastic Structures in water." *Trans. Royal Inst. of Techn.*, Stockholm, nr 82 (1954).

12 BRÄNNFORS, S "Drilling and Blasting without Removing the Overburden".(in Swedish: "Borrning och sprängning utan avtäckning"). Bergsprängning, FKO-meddelande nr 30, Stockholm (1959).

13 LANGEFORS, U. "Underwater Blasting and Blasting Without Removing the Overburden" (in Swedish: "Undervattenssprängning och sprängning utan avtäckning"). Bergsprängning, FKO-meddelande nr 30, IVA, Stockholm (1959).

Hunting Companies' Amalgamation. Hunting Aerosurveys Limited and Hunting Geophysics Limited have been amalgamated into one operating company to be known as Hunting Surveys Limited, at 6 Elstree Way, Boreham Wood, Herts. The two companies have been closely associated for many years, and Hunting Surveys Limited are now responsible for all debts and commitments of the two former companies. Hunting Surveys Limited will provide all the services to clients previously given by the two companies, and all existing contracts entered into by either company will be carried out on the same terms and conditions by Hunting Surveys Limited.

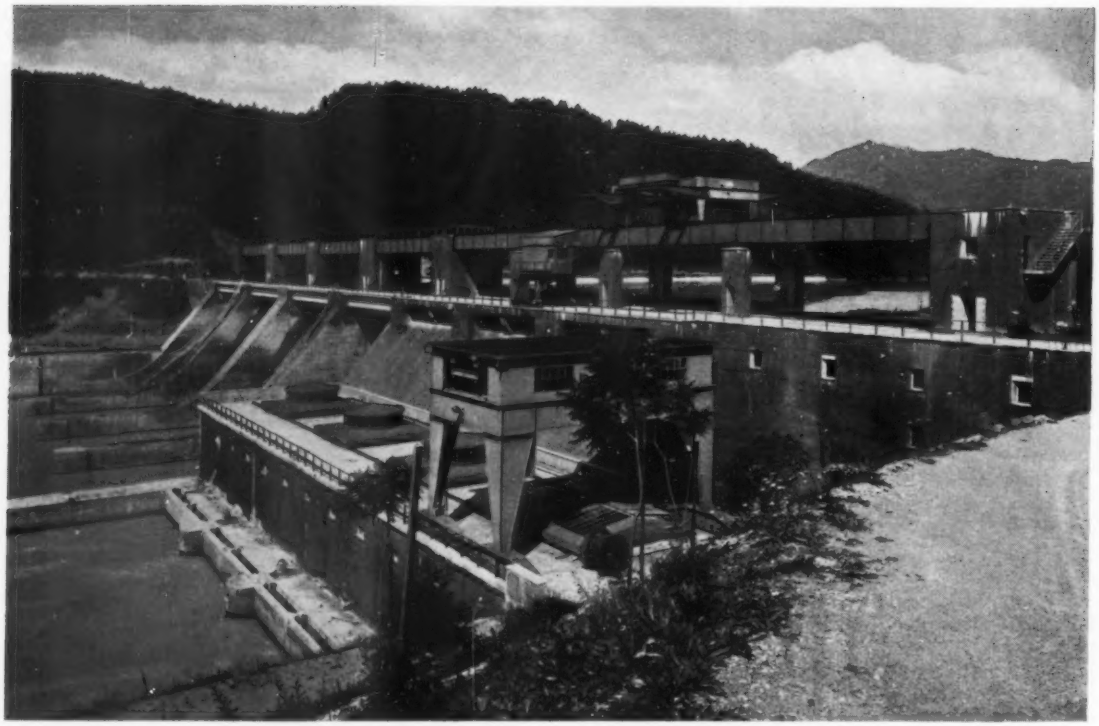


Fig. 1. The Schwabeck power plant across the Drau river viewed from downstream

Plans for the Drau

A survey is given of the existing and planned power plants on the Drau river, Austria

By DR. E. KÖNIGSHOFER

THE Drau is a tributary of the Danube and has its source in Southern Tyrol which now belongs to Italy. It flows through Austria and Yugoslavia and forms in part the border between Hungary and Yugoslavia. Its entire length is 720 km.

Even in the former Austro-Hungarian monarchy the favourable water flow of the Drau suggested its development for power production. The Carinthian section of the river falls under the influence of the Mediterranean region, having markedly heavy precipitations in the late autumn when the run-offs show the so-called "Adriatic peak." But the run-offs are relatively high also in winter and thawing sets in much earlier than to the north of the main chain of the Alps. These conditions render the water flow especially suitable for power production.

The Faal plant on the Drau was erected in the days of the monarchy but after the delimitation of frontiers in 1918 fell to the newly formed state of Yugoslavia.

When, owing to the course of events during the Second World War, the frontiers established in 1918 disappeared temporarily the Third Reich took an active interest in the development of the Drau. The Schwabeck plant was built in accordance with the plans of Dr. Grzywienski, who subsequently became professor at the Institute of Technology in Vienna. It was completed in 1943 and was designed for three 17·60 MW generating units driven by Kaplan turbines, and has a power production of 340 million kWh in a normal year. The customary power house is dispensed with and the generating units installed in shafts protected against the weather by sliding hoods (Fig. 1).

The construction of the Lavamünd power plant, downstream of Schwabeck, was commenced by the Third Reich, but was not completed until after the war by the installation of a third generating unit in 1949. The three units, which are driven by Kaplan turbines, have a capacity of 7 MW yielding an annual power production of 135 million kWh. The plant was designed as a pier plant in accordance with the plans of Dr. Grengg, afterwards professor at the Institute of Technology in Graz (Fig. 3).

The other installations initiated in the time of the Third Reich fell to Yugoslavia after the termination of the war, viz. the Unterdrauburg plant downstream of Lavamünd, the Marburg plant under construction downstream of the former Faal plant, and the site of the Saldenhofen plant. All these installations have in the meantime been completed and are in continuous operation.

Austria is now developing that section of the Drau not hitherto utilised, and in the first place, the Edling station, upstream of Schwabeck, is being constructed by the Österreichische Draukraftwerke A.G. (ÖDKW). Fig. 2.

After the end of the Second World War the Schwabeck plant was of outstanding importance for Austria's power supply. At that time the utilisation of the Drau by this plant, through intermediate storage operations, had an adverse effect upon the Yugoslavian Drau plant lying farther downstream, and an agreement between Austria and Yugoslavia now makes provision for an appropriate supply of water from the Schwabeck plant. The Edling plant at present under construction will have to arrange its operation in line with that agreement. It appears, therefore, justified to consider the Edling plant with the Schwabeck and Lavamünd plants as a unit, and the groups of power plants to be erected upstream of Edling as another separate operational unit since operation of the latter group could be carried out independently of the three power plants farther downstream.

For the section of the Drau river from Edling to Villach, which has a length of about 62 km. and provides for a head of 92 m., the ÖDKW has elaborated a project (Fig. 2) based on the assumption that a long river section can only be developed in an efficient manner by providing an overall plan, as this is the only means of ensuring optimum utilisation of the available head. In most cases, without such a concept and with a site selected arbitrarily, a considerable portion of the available head remains unused. Under the planned construction seven stages between Edling and Villach are envisaged.

The ÖDKW is operating the Lavamünd and Schwabeck plants which it has either erected or extended, and has constructed the Reisseck-Kreuzeck development (WATER POWER, February 1954). Furthermore, the thermal plants at Voitsberg and St. Andrä are being extended and the Zeltweg thermal plant is being erected.

The Edling Plant

The construction of the Edling stage was begun in February 1959. For several reasons the Edling scheme was chosen in preference to numerous other projects ready for construction:—

(1). The plant will be erected in Southern Austria, in the province of Carinthia, the economy of which is lagging behind.

(2). The project has a more than average profitability, as will be shown later.

(3). It will increase the economy of the Schwabeck and Lavamünd plants, as the silting up of the storage area at Schwabeck will be prevented and the silting up of its own storage area can be overcome in an economical manner.

The Edling project was elaborated on the basis of a thorough study of the technical and economic conditions. The catchment area was ascertained to comprise 10,656 sq. km. of which 150 sq. km. are glaciated. The mean annual precipitation over a period of 55 years amounts to 1,044 mm. A thorough examination of the water supply suggested the provision of two Kaplan turbines which were designed for a discharge of 200–213 cu. m. per sec. The maximum flood flows to be reckoned with were ascertained to amount to 3,500 cu. m. per sec., and floods during construction to be 1,600 cu. m. per sec.

An examination of topographical conditions, having regard to the storage capacity of the Schwabeck plant farther downstream, to the plant planned upstream, to the requirements of agriculture and to the settlements in the storage area, suggested the practicability of fixing the maximum water level at 390·8 m. above sea level. The storage basin thus provided will have a volume of 20 million cu. m., a length of about 20 km. and a surface of 12·2 sq. km. while its width will vary between 0·2 km. and 1·2 km. A geological examination of the weir site has been favourable in regard to both strength and stability. Storage will be regulated in such a way that the water level at the railway bridge and at the junction of the Gurk is kept within admissible limits. In case of floods of 3,500 cu. m. per sec. the admissible water

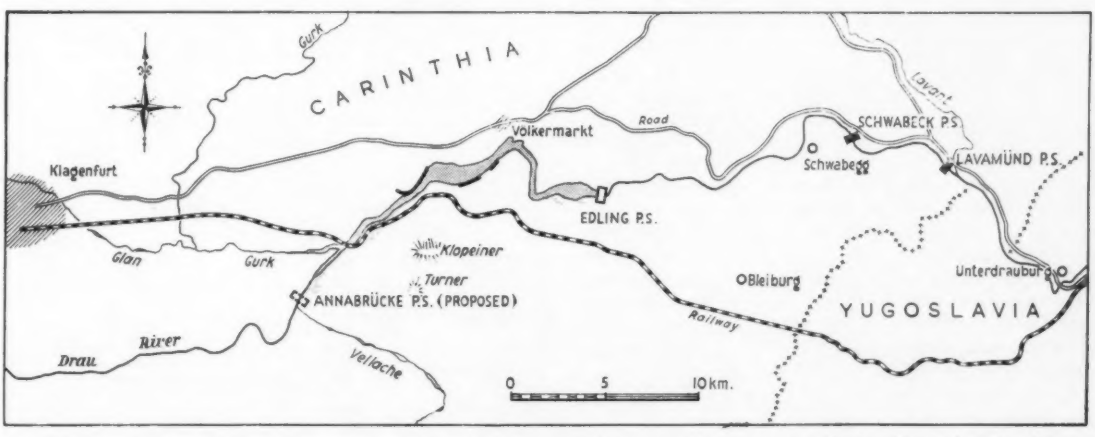


Fig. 2. Section of the Drau river under development between Klagenfurt and the Yugoslav border

Fig. 3. The Lavamünd power plant which was completed in 1949

level is not exceeded when the gates of the weir are wound up completely. Until an upper stage is erected the solids transported by the Drau, which amount to 1·25–1·4 million cu. m., 10% of which are small boulders and gravel, can be controlled by dredging operations at the weir basin.

Replacement costs for submerged items are within reasonable limits, and the same applies to the costs of damming off two settled areas.

The required constructional works consist of a dam with a length of 2·6 km. and a maximum height of 8 m., requiring 275,000 cu. m. of concrete; a dam, 1·5 km. long and 4–9 m. high; and a dam, 190 m. long and 9 m. high. Furthermore, two pumping plants will be necessary.

Before commencing the main constructional work the building site must be opened up by an access road, 6 km. long, to connect with the federal roadway system, a feeder road to the south and a feeder line about 2 km. long to the Klagenfurt-Bleiberg railway. A road will be constructed over the weir and will be left open to the public when the scheme is completed.

At the site of the weir the Drau follows a series of bends and the most suitable place for erecting the weir was ascertained by means of model tests. It lies at the end of a river bend at the inner side of which the weir will be located. The weir axis will be slightly curved in order to divert flood flows from the right bank to the left bank which curves in immediately downstream of the power house. The weir sill is at 374·40 m. above sea level. Three weir openings having a free width of 15 m. each and, on the tailwater side, segmental sluices 13 m. high are envisaged (Figs. 4 and 5).

In the power house on the left bank two vertical generating sets will be installed running at 115·4 r.p.m., each consisting of a Kaplan turbine and a three-phase generator of 44,000 kVA, 10·5 kV capacity.

In the open-air switchyard on the left bank a 90,000 kVA transformer of 10·5/220 kV will be installed. The energy produced will be conducted by an overhead line to a transformer station to be connected with the Austrian grid.

Fig. 6 indicates the flow to be expected on the basis of observations made during the years 1926–1955, and shows clearly the "Adriatic peak" in the month of November.

This flow will yield the energy output shown in Fig. 7. Some 64% of the power produced in a normal year will accrue in summer and 36% in winter.

A construction period of 28 months is considered

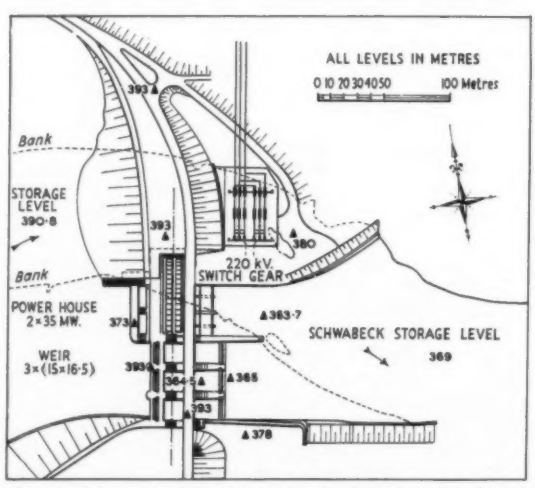


Fig. 4. Scheme of Schwabeck station showing levels

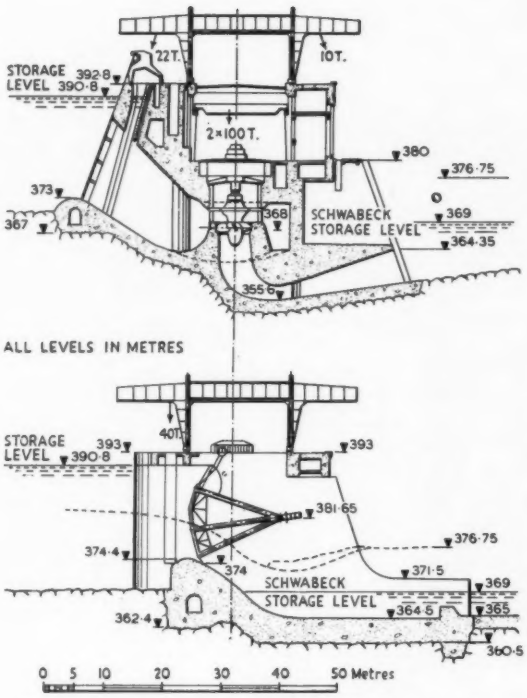


Fig. 5. Sectional elevation of Schwabeck station

to be necessary so that storage can be started by the middle of February, 1962. The first generating unit is scheduled to be put into operation on April 15 and the second on August 15, 1962.

Power Plants between Villach and Edling

The partition of a long river section into stages requires consideration of the topographical and geological conditions, of traffic roads and settlements, of flood controls, and of the operational conditions that are to be created. The latter make it desirable to form a large storage area as far as possible at the beginning of the group. Such an area is provided at the second stage, Feistritz.

As is usual in any river course divided into development stages, there are some weir sites which appear to be provided by nature. Investigations of the soil have shown, however, that certain sites cannot be used.

The larger storage area at the Feistritz stage will submerge certain areas which are not of agricultural importance but in other cases protective em-

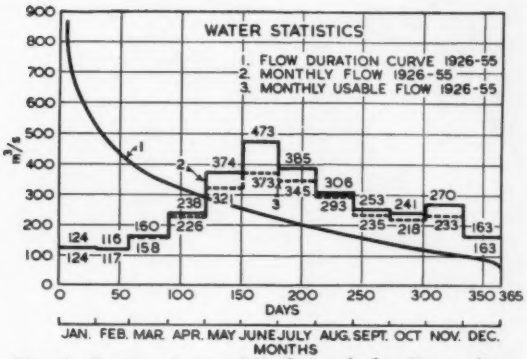


Fig. 6. Expected monthly flow of the Drau river

bankments will be necessary (Fig. 2).

Downstream of Feistritz the stages will be of similar size. In choosing weir sites account has been taken of the tributaries to the Drau which, coming from the Karawanken mountains, transport a good deal of sediment. Five stages were consequently decided upon: Hollenburg, Ferlach, Dullach, Rottenstein and Annabrücke, a selection which requires but little change in respect of the existing bridges, of which only two, viz., the Völkermarkt Drau bridge and the Anna bridge, will be affected.

Rosegg, the uppermost stage, will be constructed in such a way that part of the flow of the Drau is di-

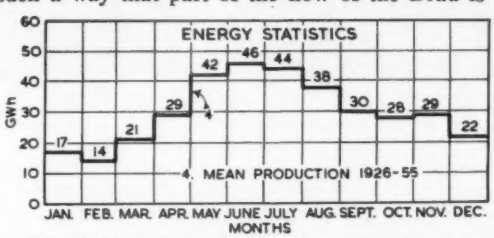


Fig. 7. The energy output from the river flow

verted through a canal. It will comprise a storage area 12 km. long and a headrace 1·7 km. long from the weir to the power house, at the end of which a basin is provided to serve as a surge tank. The storage area will function as a basin for retaining the sedimentary material and suspended substances. The weir will consist of four openings having a free width of 16 m. each. The maximum water level at 483 m. will be so controlled that existing conditions in the city of Villach will be fully safeguarded. The present floor of the storage basin will be preserved by dredging. The river bend at Wernberg, shown in

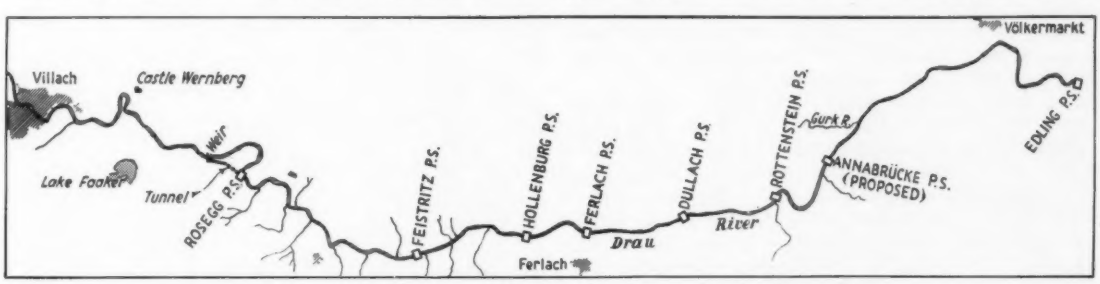


Fig. 8. Power stations, proposed and existing, on the Drau river

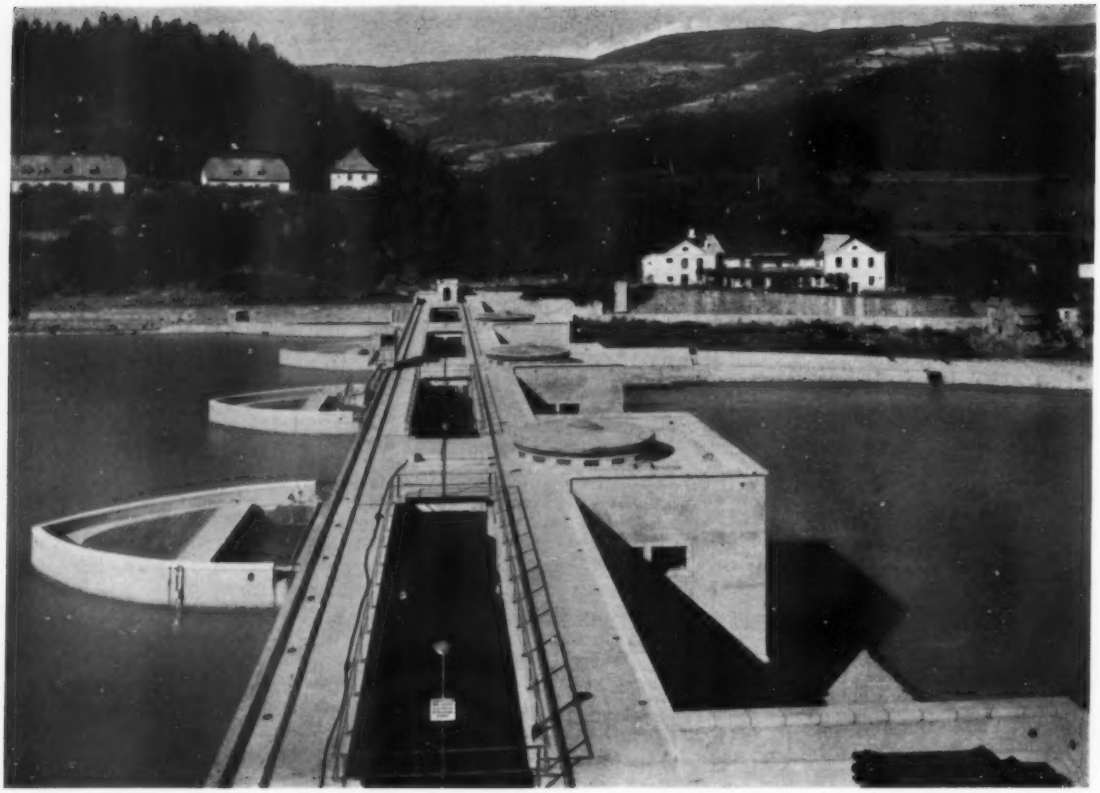


Fig. 9. An upstream view of Schwabeck power plant

Fig. 8, is to be drained by a 250 m. long intercepting cut, and the material obtained by the dredging operations will be deposited in the old river bend. The headwater canal following the intake has a length of 900 m. and feeds a 1·6 km. pressure tunnel with an inside diameter of 9 m. leading to the surge-tank basin.

The main data of this stage are:

Catchment area	..	7,090 sq. km.
Maximum water level		483 m.
Tailwater level	..	463·50 m.
Gross head	.. ..	19·50 m.
Utilisable flow	..	280·00 cu. m. per sec.
Installed capacity	..	41·70 MW
Annual production	..	223·70 GWh

The subsequent Feistritz plant has been designed as a fixed-cycle plant for the stages farther downstream. A relatively large storage area has, therefore, been assigned to it and a relatively high head has been provided. This has been done so that the capacity of the stage might not be restricted by fluctuations in the storage level. The weir at Feistritz will be constructed with girders and will comprise three openings having a free width of 19 m. each. Two generating units each consisting of a Kaplan turbine and a three-phase generator will be installed. The tributaries joining the Drau above the storage point carry much sediment which threatens to silt up the storage area. This danger is to be averted by flow controls and dredging operations at the junction.

The characteristic data of this plant are:

Catchment area	..	7,212 sq. km.
Maximum water level		463·50 m.
Tailwater level	..	437·80 m.
Gross head	.. ..	25·70 m.
Utilisable flow	..	320·00 cu. m. per sec.
Installed capacity	..	68·60 MW
Annual production	..	341·70 GWh

The Ferlach power plant does not require any special provisions for its construction. The weir, which will be erected on the left of the river, will have three openings of a free width of 16 m. each and will contain two generating units.

The main data of the plant are:

Catchment area	..	7,301 sq. km.
Maximum water level		428·60 m.
Tailwater level	..	419·40 m.
Gross head	.. ..	9·20 m.
Utilisable flow	..	320·00 cu. m. per sec.
Installed capacity	..	24·5 MW
Annual production	..	123·5 GWh

The Dullach stage will have three weir openings of 16 m. free width each and two generating units. Various dam constructions as well as flow controls will be required for the erection of this stage.

The data of this stage are:

Catchment area	..	7,455 sq. km.
Maximum water level		419·40 m.
Tailwater level	..	409·20 m.
Gross head	.. ..	10·20 m.
Utilisable flow	..	320·00 cu. m. per sec.
Installed capacity	..	27·50 MW
Annual production	..	138·00 GWh

The Rottenstein stage lies 100 m. below the

Freibach, and as that stream is already being utilised for power there is no danger that the storage basin will be silted up. Here again revetments and pumps will have to be erected, as Fig. 8 reveals.

The three weir openings envisaged have a free width of 16 m. each. Here, again, two generating units will be installed. The data of this stage are:

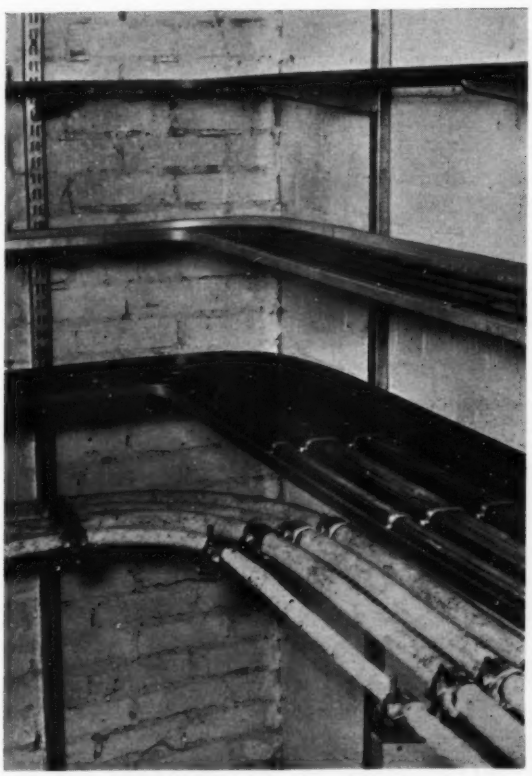
Catchment area ..	7,557 sq. km.
Maximum water level	409·20 m.
Tailwater level ..	400·00 m.
Gross head	9·20 m.
Utilisable flow ..	320·00 cu. m. per sec.
Installed capacity ..	25·00 MW
Annual production ..	126·00 GWh

The last stage, Annabrücke, will require small adjustments of the ground, the construction of embankments and the renovation of the bridge. The Vellach brook, which transports much sedimentary material, will have to be diverted into the tailwater. The weir will have three openings of a free width of 16 m. each. The data of the stage are:

Catchment area ..	7,590 sq. km.
Maximum water level	400·00 m.
Tailwater level ..	390·80 m.
Gross head	9·20 m.
Utilisable flow ..	320·00 cu. m. per sec.
Installed capacity ..	23·80 MW
Annual production ..	120·00 GWh

Spur Cable Racking System

A new cable racking system, which is extremely flexible and claimed to cut installation costs considerably in comparison with other methods, has been introduced by Savage & Parsons Limited of Watford, Herts. It is based on the Spur adjustable shelving system, but uses modified Spur components and a number of special fitments specially designed for racking so that the heaviest types of industrial and power cabling can be carried with safety. It consists, basically, of wall-mounted uprights of mild-steel channel with slots at regular intervals in the face, into which fit cantilever brackets ranging in size from 5 in. to 18½ in. To make an "island" site, double-sided uprights can be formed by bolting two slotted channels together and fixing at floor and ceiling with heavy-duty sockets.



A simple bolting system on the brackets fixes standard cable trays, or holds a Spur top plate to which standard cable clamps or cleats can be fitted. The height of the bracket can be adjusted easily by inserting the holding lugs into other slots in the face of the upright. The safe load for each bracket ranges from 280 lb. for the 5 in. to 160 lb. for the 18½ in., but considerably greater loads can be carried by using a Spur supporting strut.

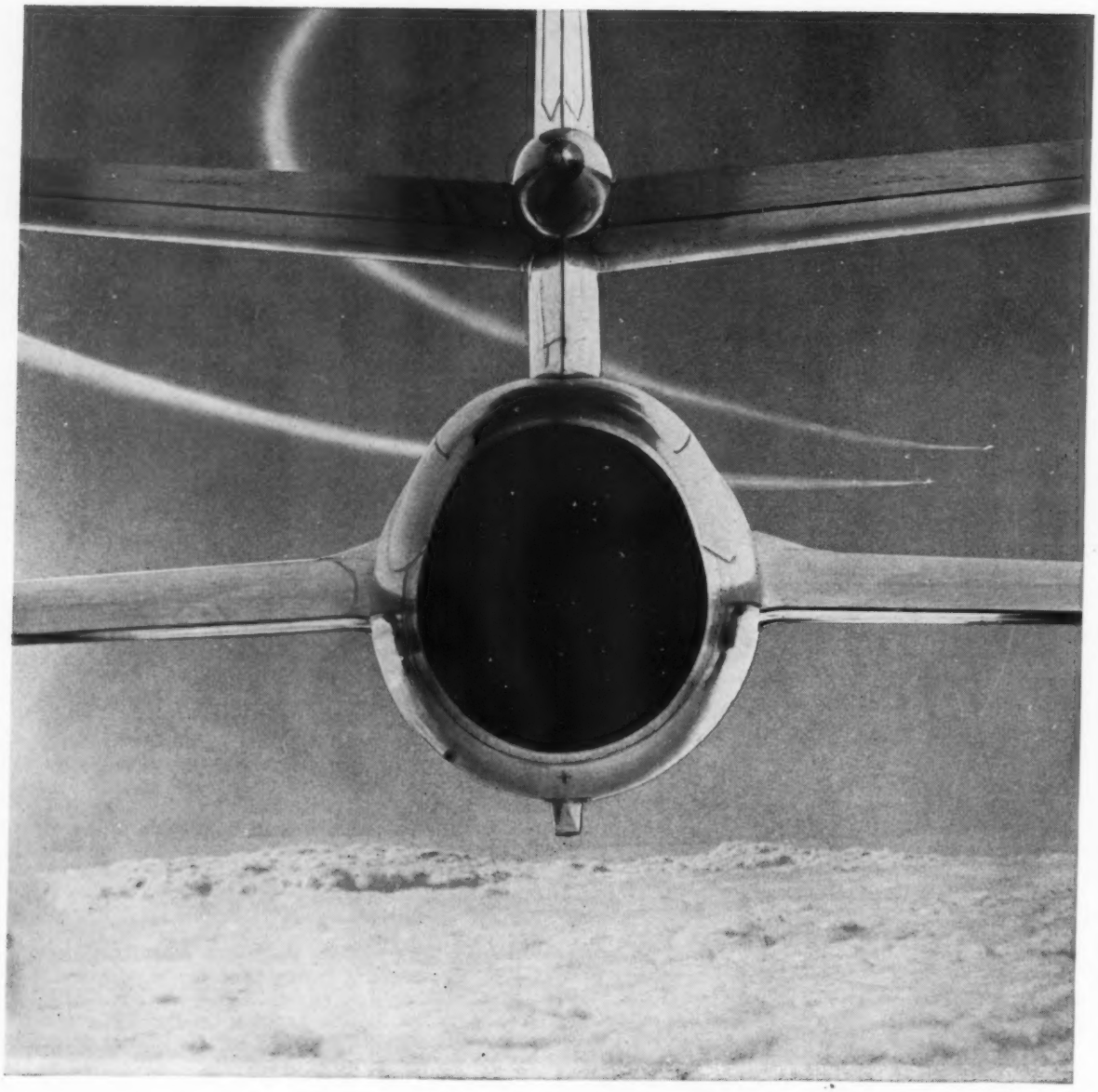
The Spur cable racking system is claimed to be ideal for power stations and electric cabling and piping installations generally, particularly where low installation costs and speedy erection work are essential. Its use also obviates detailed installation drawings and, where new buildings are concerned, simplifies *in situ* concreting work as no inserts are required. New cable runs can be added, or existing runs changed, with the minimum of inconvenience and without affecting the remainder of the installation. A leaflet describing the new system has been published by the makers.

New Bench Mounted Grinder

A new air-operated grinder has been introduced by the Consolidated Pneumatic Tool Company Ltd., of 232, Dawes Road, London, S.W.6. The grinder, known as the 3190M, has a 6 in. diameter wheel which has a width of 1 in., the free operating speed being 4,500 r.p.m. The total height of the unit is about 9 in. and the weight, including the guard, is 12 lb. The diameter of the air inlet connection is ½ in. this being a male B.S.P. thread.

Power for the tool is developed by a vane type motor, particular features of which are the constant speed governor which maintains the wheel at the most efficient cutting speed from no load to full load and eliminates the possibility of overspeed when running free, a heavy valve spring and loose fitting valve which prevents the valve from being jammed by foreign matter and a neoprene "O" ring which gives a leakproof valve seal.

Whilst the drilled baseplate on which the grinder is mounted makes it particularly suitable for attaching to portable compressors for the maintenance of tools, such as the touching up drill steels, breaker points, etc., it will also find a wide general application where occasional bench grinding tasks exist and where a supply of compressed air is to hand.



When you see a hole think of **Sandvik Coromant**

SANDVIK COROMANT is today's most widely used tungsten carbide tipped equipment for rock drilling. All over the world you will find Sandvik Coromant Drill Steels, Extension Steels and Detachable Bits.

ATLAS COPCO, world's largest company specialising solely in compressed air equipment, is the sales organisation in 90 countries of Sandvik Coromant products for rock drilling. For details contact your local Atlas Copco Company or Agent, or write to Atlas Copco AB, Stockholm 1, Sweden.

SANDVIK Coromant SOLD THROUGHOUT THE WORLD BY Atlas Copco

DS5131

Allis-Chalmers HD.6G Tractor Shovel

An Allis-Chalmers 79·5 h.p. 4 stroke diesel engine supplies power to the new tractor shovel and produces a 16,670 lb. drawbar pull. Four forward speeds from 1·5 to 5·5 m.p.h. and two reverse speeds of 2·0 and 4·1 m.p.h. can be selected with the single lever located within easy reach of the operator. The dumping height of the new unit is over 9 ft., 3 in. greater than the previous model and with a reach of 3 ft. 9½ in. at 8 ft. It has ample reach to get bucket loads out to the centre of high-sided trucks. The new curved bottom bucket tips back 40° at ground level, with a 21,500 lb. break-out force at the cutting edge, which is 500 lb. greater than the weight of the machine itself.

Solid steel booms and linkage are fully "in-line" with the lift and dump cylinders, which are positioned well away from the bucket and from dirt and rocks. Wide spaced boom pivots are straddle-mounted on the double-walled shovel side frames for exceptional stability and strength. Long six-roller tracks distribute the weight to give the machine the balance necessary for safe handling of loads at high-production speeds. Heavy-duty truck frames, guards and truck wheels are standard equipment. All the shovel functions can be precisely controlled with the hydraulic system which incorporates a gear-type pump. The operator sits in a foam padded armchair-style seat which is adjustable to his individual size and habits. Controls are grouped within easy and natural reach of any operator. A decelerator pedal and a built-in bucket level indicator add to the ease of operating the machine.

Exceptional all-round visibility is one of the many features of the new HD.6G. At the front, the new forward down-sloping engine hood design gives the operator excellent visibility of all bucket operations and ensures full bucket loads. At the rear, the tractor's slim fuel tank and stub fender gives maximum visibility of the work area.

Standard equipment includes: 1½ cu. yard general-purpose bucket; chrome-plated rods, lift and dump cylinders; heavy-duty hinged wrap-around radiator guard; 13 in. semi-grouser shoes; front idlers; positive seal truck wheels, front idlers and support rollers; full-width crankcase guard; track-guiding truck wheel guards; pusher-type fan; muffler; 24 V electric starting and lighting equipment; fuel and lubrication oil pressure, temperature and ammeter gauges; long-track rigid truck frames.

Further details of the new HD.6G can be obtained from Mackay Industrial Equipment Limited, Central Way, Feltham, Middlesex, sole concessionaires in the United Kingdom for all Allis-Chalmers industrial earth-moving equipment.

New Expansion Jointing Development

A newly formed company, Tretol-Servicised Limited, Tretol House, The Hyde, London, N.W.9, have now commenced to manufacture in England the range of Servicised expansion jointing material developed by Servicised Products Corporation, of Chicago. The products will include Kork-Pak, a pre-

Here's Air Power at
ROCK BOTTOM cost

ER6 Heavy-Duty Compressor for reliable 3-shift operation

Atlas Copco's ER6 compressor delivers air at the lowest possible cost. Designed to incorporate *every* economy factor, it combines the lowest possible running costs with low installation costs and a space saving design.

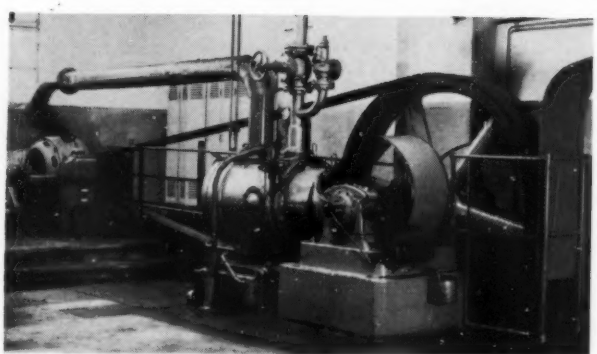
The ER6 delivers 1,075 cfm at 100 psi (30.4 m^3/min at 7 kg/cm^2) for a power consumption that is absolutely rock bottom. Thanks to a new type of intercooler, water consumption is only 440 imperial gallons (2,000 litres) per hour—a *quarter* the consumption of most similar machines. The ER6 is compact. Occupying only half the space usually required for machines of its capacity, it saves expensive factory space. In addition, installation costs are lower as new, cheaper installation methods are employed.

RANGE OF STATIONARIES

From 2.5 to 20,000 cfm, there is an Atlas Copco stationary compressor to suit every requirement. Whatever the design factor — compactness, low installation cost, low operating cost, or a combination of all three — Atlas Copco stationaries are high-performance machines you can rely on.

Sales and Service in Ninety Countries

Represented in ninety countries, Atlas Copco is the world's largest organisation specialising solely in compressed air equipment. Products include stationary and portable compressors, rock drills, loaders, hoists, air tools and paint-spraying equipment. Wherever you are, the international Atlas Copco group offers expert advice and provides a complete after-sales service.



Built to last. This Atlas Copco compressor was installed at the Bofors engineering works (Sweden) in 1907. It is still in operation.

WRITE FOR THE LEAFLET

Leaflet E1127 gives full details of the ER6 compressor. Write for a copy to your local Atlas Copco company or agent or to the address at the foot of this advertisement.

Atlas Copco puts compressed air to work for the world

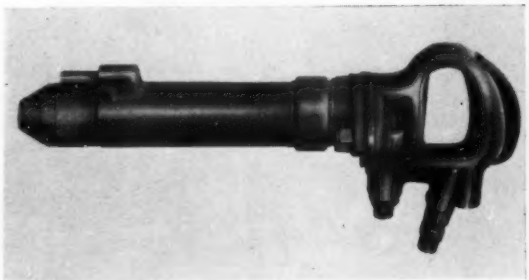
Atlas Copco AB, Stockholm 1, Sweden. In the U.K. Atlas Copco (Great Britain) Ltd., Hemel Hempstead, Herts.

SC 38

formed joint filler available in a wide variety of thicknesses up to 1 in. with remarkable powers of recovery, showing a maximum loss of only 3% of its weight after compression, as well as a comprehensive range of other expansion jointing products. New to this country is the Tretol-Servicised split-type rubber waterstop which has the advantage that it reduces the need for complicated split form work and reduces the installation cost. Other products are the Para-Plastic 41 and 44 which are sealing compounds with a high adhesive standard so that primers can be eliminated. The company will also provide technical advice and assistance on all types of expansion jointing problems.

New C.P. Wet Pick

A new wet pick, known as the FL 18W wet-type pick, has been developed by The Consolidated Pneumatic Tool Co. Ltd., 232, Dawes Road, London,



S.W.6, for use where suppression of dust by water spray is required. In this pick, water is fed to a swirl spray fitting, sited near the nose of the pick, resulting in the formation of a dense mist round the pick steel, wetting both the dust raised by the pick steel and the rock being worked. Air and water channels are independent and the pick is water controlled so that it cannot be operated as a dry machine. This has been achieved by the design of the throttle, which requires water at a pressure of 20 lb. per sq. in. before the air control becomes effective.

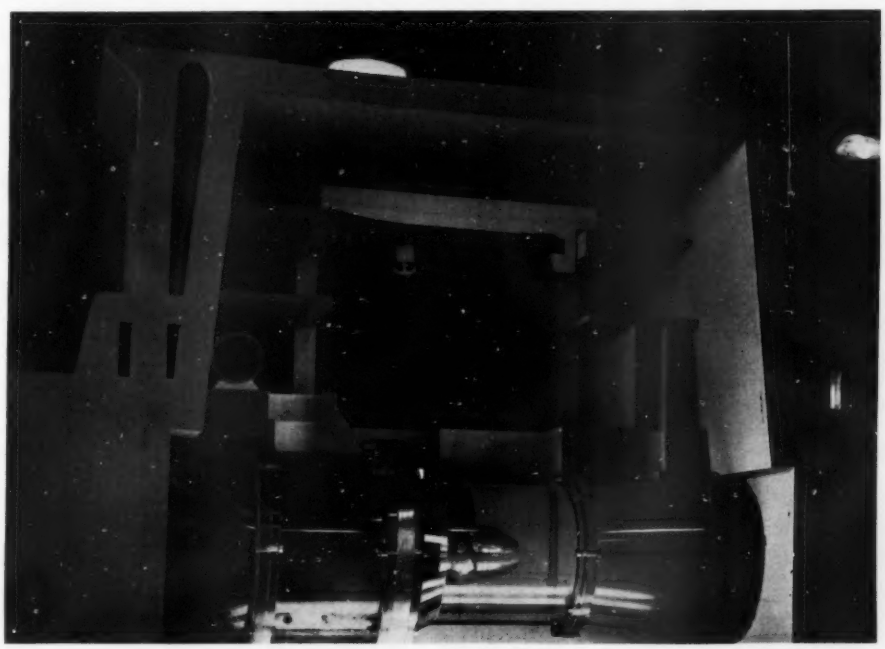
The overall length of the new pick is 19¼ in. and its weight is 23½ lb. Nipple size for both air and water inlets is ½ in. BSP. All seals and valve seats are obtained by the use of O rings, and extensive use is made of Grovelock pins. The piston stroke is cushioned to improve operator comfort. A screw-on type retainer is employed, which is locked by a rubber ring and is easily removable.

St. Malo Tidal Plant in Service

In our April issue we had the pleasure of announcing that work had been resumed on the Rance development on the north coast of France, which is the first and only tidal-power scheme in the world actually under construction. To assist the investigational work on this scheme a pilot plant was built in the St. Malo dock area and has been running experimentally for some time.

We now learn that this plant has entered into commercial service, and has thus made history as the first tidal plant in the world to furnish industrial power.

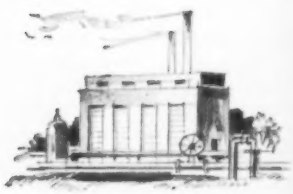
As recounted in past issues of this journal, the Rance scheme is the culmination of 17 years of work by Electricité de France, Ets. Neyrpic, the Sogreah laboratories and Soc. Alsthom, and is based on the conception of a bulb-type axial-flow unit which can function either as a pump or as a generator and with the water flowing in either direction. These four alter-

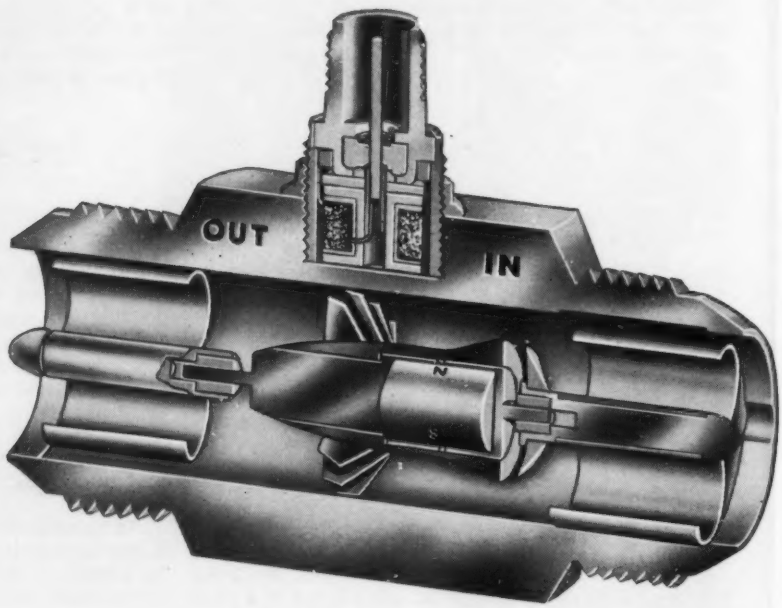


Wherever information on fluid flow is required,

the de Havilland POTTERMETER

sets new standards of accuracy and reliability





This new turbine-type flowmeter enables major advances to be made in the techniques of flow measurement and control. The de Havilland Pottermeter is the only flowmeter which offers all these features:

Accuracy to ± 0·1% or better on repetition work, ± 0·5% or better over a 20·1 range. Calibration remains constant over wide flow ranges.

Contains only one moving part—no thrust bearings—demands a minimum of maintenance.

No larger than the pipeline in which it is installed—may be mounted in any attitude.

Can be supplied with indicating, recording and process control equipment—gives digital presentation of results.

Can measure volumetric or mass flows.

Models available to measure flows from 0·1 to 40,000 Imperial gallons per minute, at a wide range of operating pressures. Larger and smaller sizes made to order.

Manufactured as standard in stainless steel—can be made in any non-magnetic material.

The de Havilland Pottermeter will be demonstrated on
STAND Q.730
at the
I.E.A. EXHIBITION
Olympia
May 23 to 28

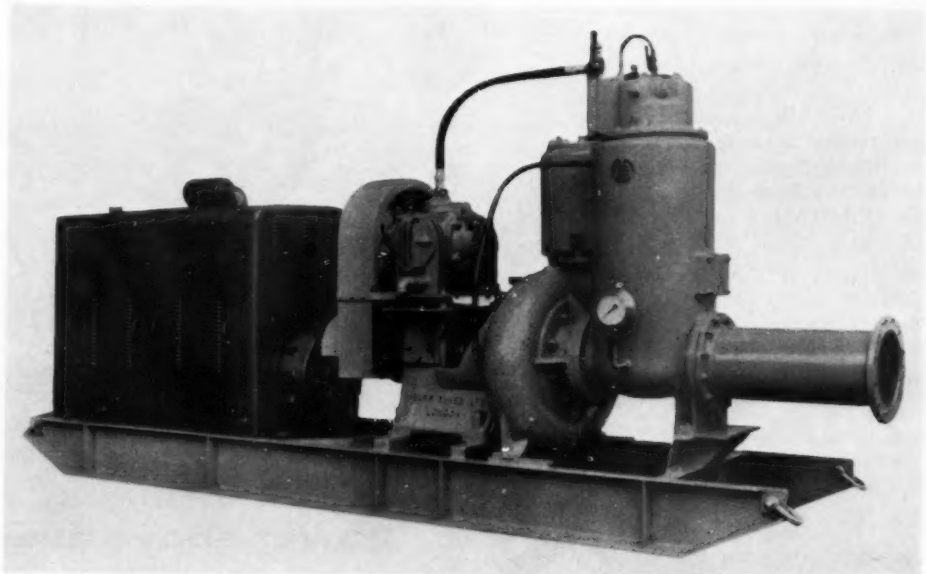
Write now for further details to:

DE HAVILLAND PROPELLERS LIMITED
(INDUSTRIAL SALES DIVISION) Hatfield, Herts

native modes of running make it possible to devise a schedule of operation in which the periods of power generation can be made to coincide with those of peak demand whatever the condition of the tide.

The St. Malo machine was a joint product of Neyrpic, Alsthom and Jeumont, and a working model of the installation is depicted in the accompanying illustration.

The Sykes 12 in. Univac Pump



The latest addition to the range of "Univac" centrifugal pumps produced by Henry Sykes Limited, of Southwark Street, London, S.E.1, is the UVS12, a 12 in. pump capable of delivering 3,500 g.p.m., against a total head from all causes of 32 ft. Particular features are the unchokeable and extremely rapid priming effects. These have been achieved by providing a separate vacuum pump to evacuate any air which may become entrained in the pump body, thus enabling the impeller and volute to be designed purely for pumping duties as distinct from the normal compromise in self-priming centrifugal pumps where the self-priming and pumping duties are combined with a resultant efficiency loss.

The major components of the pump are thus a vacuum pump, mounted for direct drive off the engine shaft, the "Univac" self-priming equipment, mounted on the suction side of the pump, a high efficiency unchokeable centrifugal pump and a reflux box on the delivery side of the pump.

The vacuum pump is a twin cylinder horizontal air-cooled unit and is mounted above the flexible coupling which takes the drive from the prime mover to the centrifugal pump. It is connected to the "Univac" equipment through a small pipe. The "Univac" equipment consists of two tanks, a primary and a secondary, the height of which are appreciably above the level of the centrifugal pump chamber. The primary tank contains an Onazote float which actuates a piston and valve through a valve holder and rubber buffer. This primary tank is connected to a secondary tank which is equipped with a ball valve and rubber seating, the outlet from this tank being the inlet to the vacuum pump. As the level of the "Univac" equipment is above that of the unchokeable pump chamber and precedes it in the suction line, any air being drawn into the suction is released into the primary tank and so does not pass into the pump chamber; on priming the pump, any air contained in the pump chamber is drawn up into the primary tank.

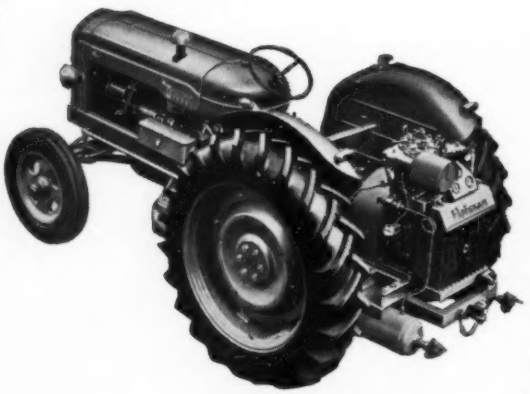
The reflux valve box which is fitted on the discharge side of the pump, contains a hinged clack valve with rubber seating. The function of this unit is not only to smooth out the discharge from the pump, but primarily to provide a non-return valve which prevents air being drawn into the pump during priming.

Thus when the pump is being primed, the hinged clack valve in the reflux box is held down against its seating by atmospheric pressure, sealing the pump on the delivery side. The Onazote float is unsupported and holds the valve holder open, air being drawn out of this tank, the pump suction and pump chamber, through the secondary tank for delivery to atmosphere by the vacuum pump. As the water rises up the suction to fill the pump chamber and the primary tank of the "Univac" equipment, the Onazote float rises, closing the valve holder and the water pressure lifts the ball valve contained in the reflux box on the delivery side.

The duty of the secondary tank in the "Univac" equipment is to prevent water from reaching the vacuum pump, this being achieved by using a wooden, rubber-covered ball valve in the secondary tank, which floats to seal the connection to the vacuum

Right on the Site:
Air power by
HOLMAN TRACTAIR

Wherever a Fordson tractor can go, there's a reliable source of air power for road making, road maintenance, concrete breaking, pumping, demolition, and heavy work of all kinds.
The HOLMAN TRACTAIR is a simple, efficient compressor manufactured to the exacting standards of all HOLMAN equipment, and mounted on the rear of a Fordson Major tractor. Two models, the TRACTAIR 8 and 13, deliver 71·5 and 110 c.f.m. respectively at 100 p.s.i. Both are driven from the power take-off shaft of the tractor gearbox.



Power above average:
the HOLMAN SS25
Road Ripper

Hard-hitting and intended for the toughest work, the SS25 Road Ripper has a latch-type retainer. In most respects the SS25 is identical with the SS22 which is known for its above-average power without excessive air consumption.

ALL HOLMAN compressed air equipment is famous the world over for long, efficient and economical life.

Write for catalogue 5/A3/SP17

Air... compressed air... **power...** Holman

Holman Bros. Limited, Camborne, England; Camborne 2275 and at 44 Brook Street, London W1; Hyde Park 9444.
Also in Birmingham · Cardiff · Glasgow · Peterborough · Sheffield. Australia · Canada · East Africa · France India · South Africa · Spain · U.S.A. · West Africa. With Agents and Representatives throughout the world.

HM32

pump in the event of water being drawn into this chamber due to improper operation of the Onazote float.

Other devices fitted include an automatic trip which governs the level of the water in the primary "Univac" tank and admits air to it in the event of its rising beyond a predetermined level. An air cock is also fitted and this enables the vacuum to be broken while the pump is running, thus allowing a rapid flow of water back down the suction. This is particularly useful in clearing a blocked suction. An auxiliary snift valve is also fitted and this is for operation where the pump is employed with a very short suction lift and a small delivery head. In such a case the output obtained would be much in excess of the pump's capacity, causing turbulence in the primary "Univac" tank with the formation of spray which would be carried over to the secondary tank. The adjustment of the snift valve will lower the water level in the primary tank, while maintaining efficient operation, thus keeping the secondary tank dry.

The unchokeable pump can handle large solids and abrasive sludges of up to 60% solid content, the nature of the material being handled in no way affecting the operation of the "Univac" equipment. The head/quantity characteristics of the pump are almost flat over the working range and fall continuously from zero output.

While the design of the equipment makes the pump particularly suitable for operating where large volumes of air may be encountered due to variations in the suction, as in wellpoint dewatering systems and tunnel driving, it will also be of interest where large volumes of water are required to be pumped and where no loss of priming can be tolerated for any reason.

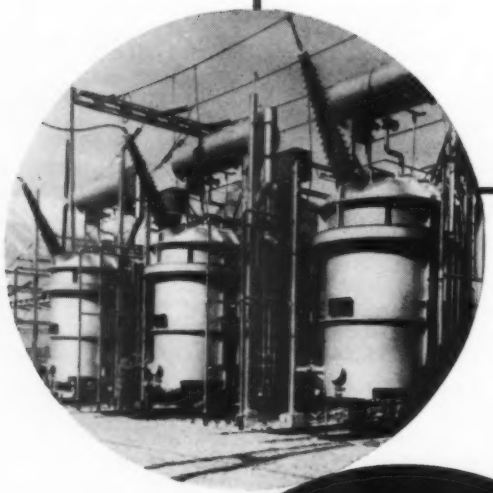
Abstracts from the World Technical Press

Stalingrad Power Station

A detailed description is given of this great Volga development which, with its 2·53 million kW installed capacity will, when completed, exceed Kuibyshev by no less than 230,000 kW. In layout, the works do not differ very substantially from the Kuibyshev installations. The power-house block is not set up in a cove on the left bank of the river, as at Kuibyshev, but in the river bed itself, an earthfill dam connecting it to the left bank. In addition, the spillway block and the power house are separated by a fish-pass, and, on the right bank, the double navigation locks, each with two chambers, are inserted between two earthfill dams. (A. V. Michailov and I. S. Kharitonov, *Gidrotekhnicheskoe stroïtelstvo*, Vol. 28, No. 1. January 1959, p. 6, 10 pp., 9 ff.)

Supply and Transport Problems at Bergell Sites

In view of the uncommonly broken region of the Grisons and of the altitude at which some of the installations are sited, the builders of the Bergell plants had to cope with exceedingly complex and awkward problems in respect of the supply and transport of no less than 250,000 tons of material and more than 200,000 tons of cement over distances varying between 120 and 224 km. by road, and reaching 285 km. by rail. The bulk of the supplies went by rail from Zurich to Chur; there the Rhaetian Railway took over from the Federal Railways to convey the goods to St. Moritz, whence lorries carried them some 23 km. to the Maloja Pass, 1,460 m. above sea level, then over a difficult, zig-zag road 370 m. below to Casaccia. Six sets of excellent block graphs show month by month the progress of tunnelling and excavation work, concreting, transport, cableway performance, generation and consumption of electricity in conjunction with construction work, and manpower utilisation. A heavy-duty 16 ton cableway conveys fully-loaded lorries from the bottom of the valley 835 m. higher up to the mountain station of Sasc-Prümaveira, where a 1·5 km. road leads to the dam site, 2,100 m. above sea level. This cableway, which mainly deals with the transport of oil and heavy pieces of equipment for the construction plants, also attends to the conveyance of personnel at the rate of 60 men a ride, and is frequently used by sightseeing parties. The concrete batching and mixing plant, a five-floor building, turns out an average of 4,000 cu. m. a day requiring a supply of 10,000 tons of gravel and sand. The plant crushes 90–120 cm. aggregates to 15 cm., and four lines of screens separate it into five sizes, from 0–3 to 80–150 mm. Mixing is carried out in a Johnson tower of the traditional type and four 3 cu. m. Koering mixers. Vibrators compact the concrete, which is spread preliminarily by bulldozers. A double-page folder with excellent line illustrations shows the details of most of the construction plants. Concrete distribution at the dam is ensured by four 10 ton blondins, of which three, operating in parallel, are mounted on travelling towers, while the fourth, carried by stationary counterbalancing towers and running above the dam crest, is used in the main for placing the layers of concrete at the uppermost points. The flanks of the dam, which are inaccessible to the blondins and recede upstream towards the valley walls, are served by rotary tower cranes. Out of a grand total of 970,000 cu. m. of concrete, over 100,000 tons were placed during each of the months of July and August 1958, the highest daily output exceeding 5,000 cu. m. The extent of the installations supplying the construction sites with electric energy is shown by the estimated consumption during the whole of the construction period, up to the end of 1960; it amounted to 41·8 million kWh. The aggregate power output of the vehicles, excavators and lorries utilised by the contractors is assessed at 5,500 h.p. at the dam site alone and 2,000 h.p. at the valley-bottom installations. The number of workers employed reached its peak of about 1,040 men in September 1956. The number of working hours for the whole construction period is assessed at 9·5 million, corresponding to a total of 27 million Sw. Fr. in wages. Canteens and sleeping quarters (1,120 beds in the summer of 1956), with all the necessary sanitary installations, have been provided at a cost varying between Fr. 2,500 and 3,000 a head, and totalling Fr. 3 million. A separate table shows the extent to which mechanisation has been



Power Stations and Substations

Sécheron

Sécheron Works Co Ltd, Geneva, the specialists in the electrotechnical field, supply all kinds of equipment for complete power stations and substations:

High capacity A.C. and D.C. motors and generators. Power transformers of all sizes and voltages. Automatic regulators for various types of controls. Pumpless mercury arc rectifiers, semi-conductor rectifiers.

Further lines of production: Electric traction equipment, Welding sets and electrodes.

S.A. des Ateliers de Sécheron, Geneva, Switzerland

G 101 a

applied at the Bergell installations in relation to manual work. (Dipl. Ing. Bertschinger, *Wasser- und Energiewirtschaft—Cours d'Eau et Energie*, Vol. 51, No. 7, July 1959, p. 191, 8 pp., 3 tables, 19 ff.)

NOTE: We wish to draw attention to Ing. Bächtinger's article in *Technische Rundschau* (Vol. 51, No. 47, November 13, 1959, pp. 33 and 35, 9 ff.), which contains interesting details on the same subject, especially on the procedures applied to the transfer of heavy pieces of equipment and cement from the standard-gauge Federal Railways to the narrow-gauge Rhaetian Railway at Landquart and Chur, and from the Rhaetian Railways to road transport at St. Moritz.

Tunnelling at Roselend

Except for a 75 m. long section, in a triassic zone of crushed rock, the 12·6 km. pressure tunnel which feeds the turbines of the La Bathie plant from the Roselend dam, runs through crystalline schists of excellent behaviour. This dislocation is dominated by the hollow of the Grande Combe pass, which it probably drains, and its safe crossing required extensive investigations, followed by a special treatment of the surrounding ground, which is described in detail in this paper. This treatment consisted in building a ferro-concrete wall, and drilling under its protection boreholes into the zone to be tunnelled. Subsequently, cement grouting under high pressure was carried out, after chemical injections into the boreholes had brought about within a fairly short time silicatisation by gelling. It was also discovered that gelling sealed up the ground at the level of the smallest interstices, and improved the cohesion of the surrounding zone. The main action of cement grout is, in this instance, similar to that of a hydraulic jack, that is to say it drains the ground by driving the water out of the zone treated. (J. P. Lajeat and M. Court, EDF, *Construction*, Vol. XIV, No. 7, July 1959, p. 193, 9 pp., 17 ff., 2 tables.)

NOTE: Another article on the Roselend-La Bathie plant is included in *Schweizerische Zeitung*, Vol. 77, No. 35, August 1959, p. 563–566, 6 ff.)

Beechwood Development

Presented at the 73rd Annual General and Professional Meeting of The Engineering Institute of Canada, Toronto, Ontario, this paper deals especially with the geological features and foundation treatment at the Beechwood development of The New Brunswick Electric Power Commission, which is located on a north-south reach of the St. John River slightly over 100 miles north of the City of Fredericton. The structures consist of gravity-type concrete sluice and regulating sections, a fishway, an intake and power house, a gravity-type western abutment with a compacted embankment at the eastern end; the overall length of the structures is about 1,750 ft. and their maximum height above rock, 80 ft. The physiography of the river basin, overburden, bedrock, construction site, surface geology and site investigations are described and discussed. Separate paragraphs are devoted to construction materials and construction work, special stress being laid on grouting pattern and procedure, and results of the grouting programme are appended. Both blanket and curtain grouting appear to have been effective, and the fault zone in the westerly section of the intake has been successfully sealed. In the sluice section, the sump collecting the drainage from the contraction joints, from the rock drainage system under the structures, and from the observation wells drilled into rock every 5 ft. along the inspection tunnel, showed an inflow of less than 2 g.p.m. This is indeed a very low figure, when one considers that these rock drains alone are draining an area in excess of 60,000 sq. ft. (I. D. MacKenzie and E. L. Brown, *The Engineering Journal*, Vol. 42, No. 12, December 1959, p. 54, 9 pp., 8 ff.)

Computers for Hydro-Electric Problems

There is every reason to expect that digital computers will shortly play an important part in hydro-electric system analysis. Such problems as waterhammer, surge-tank effects, speed regulation and governing stability may soon be solved in a few hours of machine-computation time for individual hydro-electric installations ranging from reservoir to load centre. The basic idea of the new approach is to have a digital computer solve simultaneously all the equations pertinent to a given installation to obtain the best answers that present physical knowledge will permit. By varying important factors, such as surge-tank size, machine inertia, and governor characteristics, noting relative effects and making as many runs as necessary, it would be possible to determine optima for design and operation, and speculation would be reduced to a practical minimum. The technical details of obtaining comprehensive computer solutions using the new approach have been proposed by the writer and accepted by the Corps of Engineers as a basis for development of IBM 704 machine-computational programmes. These programmes have been under development since June by the Massachusetts Institute of Technology under contract with the Corps of Engineers, and will require about two years to complete. Machine programmes will be developed for the Oahe and Garrison power-plant systems on the Missouri River and, possibly, for one other system, as yet undesignated. (Nicholas L. Barbarossa, *Engineering News-Record*, Vol. 163, No. 23, December 3, 1959, p. 51, 1 f.)

Uruguayan Projects

In addition to the general statistics of energy production in Uruguay, this bulletin of the "Administración General de las Usinas Electricas y los Telefonos del Estado" gives a short description of two new Uruguayan projects. The Paso del Puerto scheme is to be set up near the locality of the same name on the Rio Negro, 109 km. downstream from the Baygorria plant now in course of construction. It is based on a catchment of 60,200 sq. km., and the reservoir created will cover an area of 190 sq. km. There is a choice of two sites for the dam: either near the Cerro Navarro or the Parque Bartolomeo Hidalgo. The reservoir level would reach 38·00 m. above the Montevideo elevation or 19·15 m. above the Rio Negro level, for a discharge of 1,050 cu. m. per sec. The plant will comprise a machine hall housing four 44,750 kW generators driven by Kaplan turbines at 83·4 r.p.m., a spillway block with eleven 11·70 m. openings controlled by sector gates with individual drive. This plant will increase the amount of energy supplied to the city of Montevideo by 685 GWh per annum. The Salto Grande project is an Argentino-

Uruguayan venture to include a power plant in the Ayui region on the Rio Uruguay, which actually forms the border between the two countries. The catchment involved totals 251,600 sq. km., and the dam will create a head of 27·5 m. There will be an installed capacity of 1·4 million kW in twenty 70 MW Kaplan units, and production is assessed at 6,000 GWh. Other works will include navigation locks on the Argentine side between the spillway and power-house blocks, as well as an international road bridge. (*UTE*, Vol. 5, May 1959, No. 5, p. 22, 5 ff.)

Model Investigation of Dam Stresses

This paper is devoted especially to the model tests carried out at the Laboratorio Nacional de Engenharia Civil in Lisbon with a view to determining the stresses resulting from the deadweight of the structure in concrete dams. This problem is of particular importance in the case of arches with a marked double curvature, as well as for gravity and buttress dams for which the usual analytical methods are inadequate. The methods applied to the experimental determination of these stresses are summarily reviewed, a more detailed analysis being applied to such special cases as inversion of the model, immersion in heavy liquids, concentrated loading, and construction by stages. In their conclusions, the authors emphasise the advantages of construction by stages, which not only makes the choice of materials easier but also facilitates the study of the stresses due to the deadweight of the structure. (J. Lagina Serafim and J. Poole da Costa, *Electricidade*, No. 11, July–September 1959, p. 203, 8 pp., 9 ff.)

Scour Control

In a study of scour control below spillways, particular stress is laid on hydraulic model tests. In section 1 of this paper, the author deals with the factors governing the design of protective works, discharge, head and energy drop, bed material and foundations, hydrology of the catchment involved, and construction materials. Section 2 considers the general case of energy dissipation for both high and low head by the formation of a roller and hydraulic jump, or by breaking up jets and their impact. Later sections are devoted to the various methods of dissipation and scour protection, and several instances of existing anti-scour structures are discussed. (D. V. Joglekar, *Irrigation and Power*, Vol. 10, No. 1, January 1959, p. 52, 25 pp., 20 ff.)

NOTE: In the above-mentioned journal, D. V. Joglekar also discusses the "Principles of Hydraulic Model Studies and their Limitations" (p. 86, 21 pp., 9 ff.). The same issue contains a fairly comprehensive survey by K. L. Rao of "Advances in Earth Dam Design and Construction," p. 21, 31 pp., 18 ff.)

Drava River Developments, Yugoslavia

A survey is given of the contribution made by the power plants of the Drava River, called Drau in Austria, to Yugoslavia's energy requirements. Discharge fluctuations of the river in the course of a year differ from that of most other Yugoslav rivers, and the author attempts to assess these differences in figures, as well as to indicate their influence on the electricity supply system of the country. In the first part of his article, he compares the hydrological characteristics of the Drava with those of the Cetina, Drina, Danube and Narenta, both as to probable discharge in individual months and to the storage volume required as an annual balancing factor in the course of a hydrological year. The second part deals with the conditions available in the Yugoslav power grid in connection, on the one hand, with the utilisation of the Drava development, and, on the other, of the run-of-river plants set up on other Yugoslav streams. The mean annual production is equal in either case. This comparative study shows that the Drava discharge varies less than that of any other Yugoslav river, can be much more accurately forecast, and requires the smallest storage space as a balancing factor in a hydrological year. The importance of the Drava River is proved beyond question by the fact that, upon completion of its full development, fluctuations in the output of the water-power plants within a year will be smaller, their minimum output will rise, requirements in storage space will decrease, and thermal production will play a lesser part in fulfilling the country's requirements. (Hrvoje Požar, *Electrotehniški Vestnik*, Ljubljana, Vol. 27, No. 7/8, July–August 1959, p. 209, 10 pp., 9 graphs.

NOTE: A German translation of the Slovenian text of this article, less the graphs, is included in the above issue.

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

Displayed classified advertising for situations vacant, situations wanted, public appointments, are accepted at £2 10s. 0d. per column inch.

CONSTRUCTION EQUIPMENT FOR SALE

One LIDGERWOOD Travelling Cableway, 20 U.S. capacity, for a span of 438 m., complete with two 100 ft. high travelling towers and all necessary electrical and mechanical equipment.

One HENDERSON 10-ton Electrically-driven Travelling Aerial Cableway with motions for hoisting and travelling, also for travelling of head and tail carriages, all operated by electric power by driver located on elevated platform on head support. Cableway arranged for a span of 1,180 ft. (360 metres) and designed to suit future conversion to a span of 1,443 ft. by provision of new ropes.

One KENNEDY VAN SAUN Main Crusher—No. 30 of 30 in. × 115 in. aperture, with 150 h.p. motor, 380 V, 150 r.p.m. Complete with starter.

Hidro Eléctrica Do Cávado, Rua De Sá Da Bandeira, 567, Portugal.

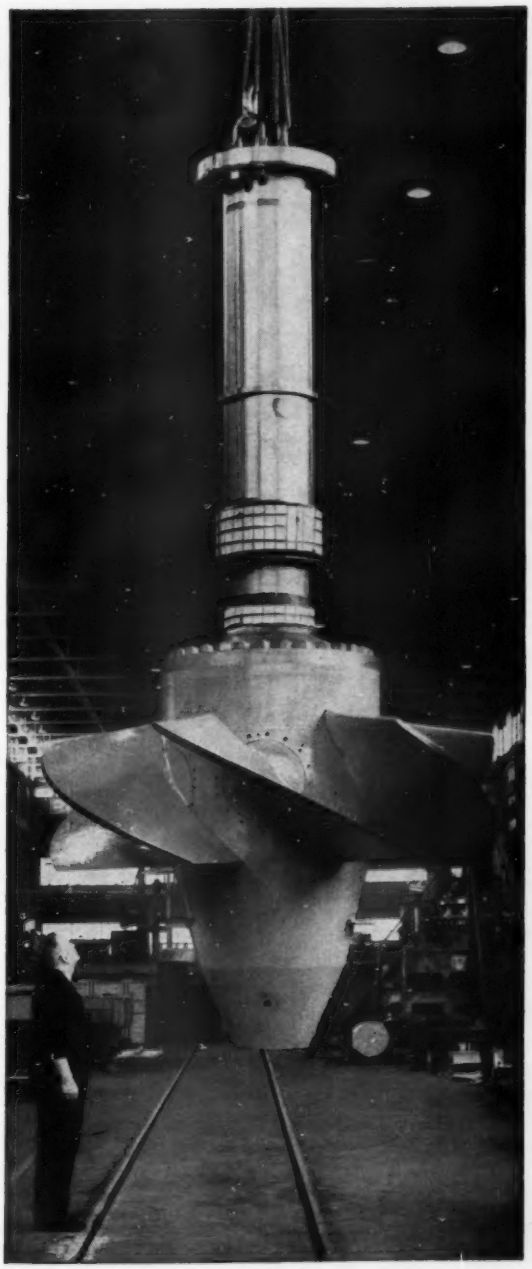
SHOTBLASTING—METAL SPRAYING COATING

Epikote, Araldite, P.T.F.E., P.T.F.C.E., Polythene, P.V.C., Neoprene and Hypalon coatings applied on SITE or at WORKS. Loyne Limited, Margaret Street, Ashton-under-Lyne, Lancs. Tel. No. ASH 4551/2/3.

EDITORIAL ASSISTANT

A YOUNG ENGINEER (25–35) will shortly be required as editorial assistant to this journal. His qualifications and experience should preferably, but not necessarily, be in civil or hydraulic engineering or in laboratory work. An aptitude for technical writing is essential and some knowledge of languages would be an advantage. The right candidate would be trained with a view to the eventual editorship. Applications should be addressed to The Editor, WATER POWER, 33 Tothill Street, Westminster, London, S.W.1.

SHIP TO: GREAT LAKES POWER



The blades of a Kaplan Turbine automatically adopt the most efficient angle to compensate for variations in the water flow or the required power output.

For this reason, Kaplan Turbines are usually installed in run-of-river plants under a low or medium head of water, and where the power load is subject to considerable variations.

The Dominion Kaplan Turbine shown, is installed at the Gartshore Falls Development of the Great Lakes Power Company in Ontario. Both this runner and a similar one at the Cat Falls Powerhouse of the Company develop 30,300 h.p. They are the two highest head Kaplan Turbines anywhere in the U.S. or Canada. Both operate in unattended, remote-controlled stations, and they incorporate features which were entirely developed and designed by Dominion engineers to ensure reliable and trouble-free service.

These turbines supply power to Sault Ste. Marie, Ontario—one of Canada's major steel producing centres.

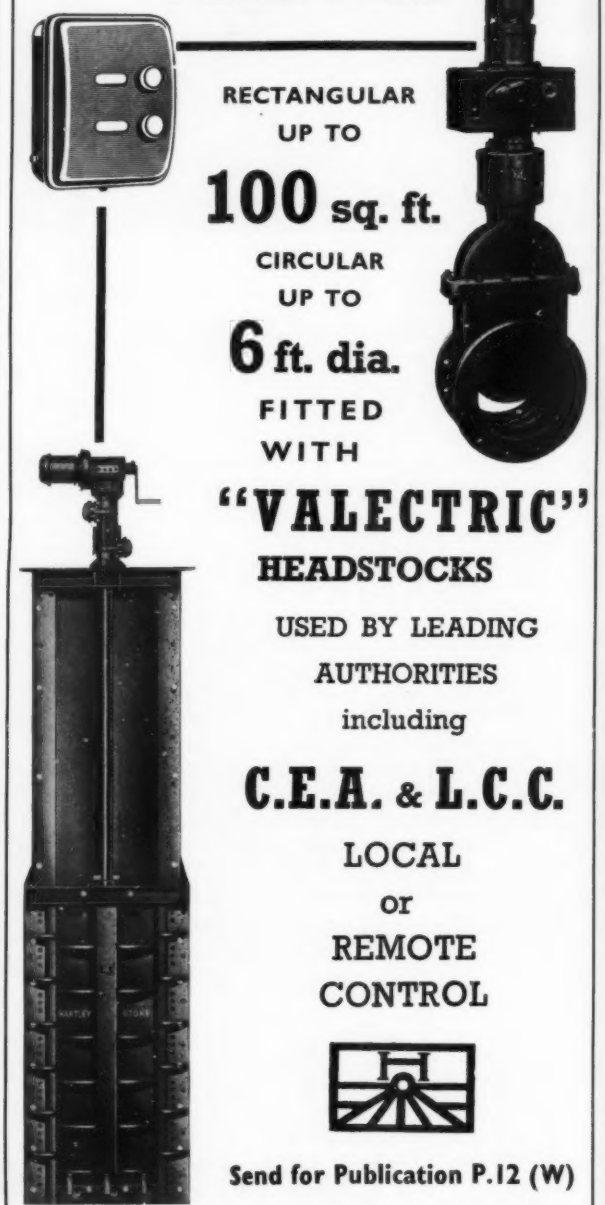
DOMINION ENGINEERING
COMPANY LIMITED

Head Office: P.O. Box 220, Montreal, Canada • Branch Offices: Toronto—Vancouver

HIGH
ENDEAVOUR
Ceretti & Tanfani have been pioneering cableway and ropeway development for nearly 70 years.
The cableway shown here places 350 tons of concrete per hour. The span is over 3,000 feet and the masts are 360 feet high. It is helping to build the Rihand Dam in India.
In Switzerland at Grande Dixence another Ceretti & Tanfani cableway has a capacity of 950 tons per hour.
Ropeways, Cableways, Cranes, Bulk handling plant, Silos—our experience covers all mechanical handling equipment and is at your service.
CERETTI & TANFANI
ROPEWAY CO. LTD.,

CERETTI & TANFANI ROPEWAY CO. LTD.
Imperial House, Dominion St., London, E.C.2
CERETTI & TANFANI S.p.A.
Via Durando 18, Milan, Italy

ELECTRICAL CONTROL OF PENSTOCKS AND VALVES



RECTANGULAR
UP TO
100 sq. ft.
CIRCULAR
UP TO
6 ft. dia.
FITTED
WITH

"VALECTRIC"
HEADSTOCKS

USED BY LEADING AUTHORITIES including

C.E.A. & L.C.C.

LOCAL
or
REMOTE
CONTROL

Send for Publication P.12 (W)

HARTLEYS (STOKE ON TRENT) LTD.

Head Office & Works: Stoke-on-Trent, England
London office: Hastings House, Norfolk Street, Strand, W.C.2

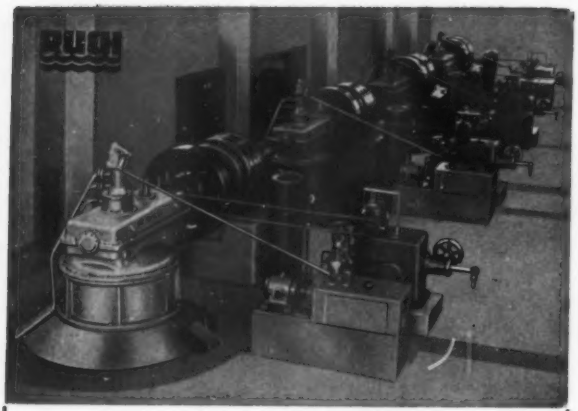
20s

CHARMILLES

HYDRAULIC TURBINES

—CHARMILLES ENGINEERING WORKS LTD., GENEVA—

TWO 88,000 HP VERTICAL SHAFT, FOUR-JET IMPULSE TURBINES FOR BRAZIL



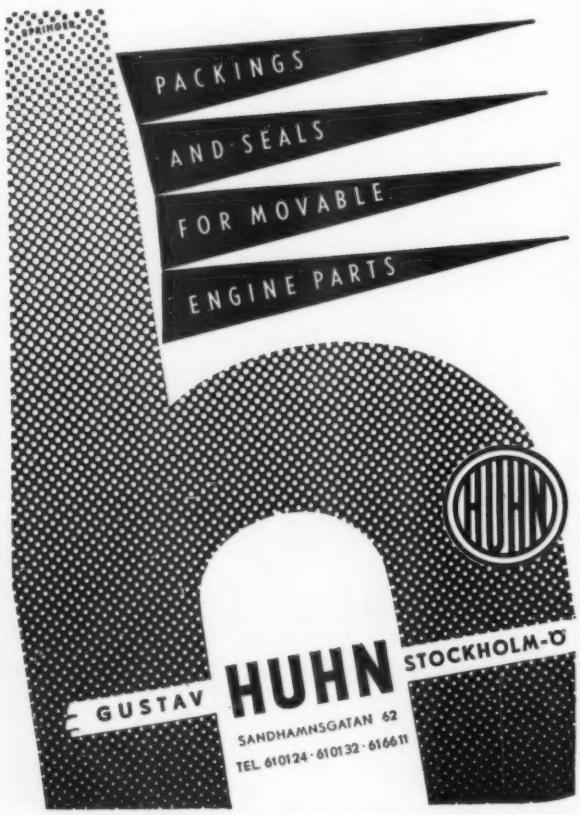
KAPLAN, IMPULSE & FRANCIS TURBINES

up to about 3,000 h.p. and other machinery such as governors, gear mechanisms, screens, trashrakes, conduits and shut-off valves, etc.,

are manufactured, in the traditionally high quality of the Black Forest, by:

MASCHINENFABRIK EDUARD RUCH

OBERKIRCH 2 · BADEN · GERMANY



THE RAILWAY GAZETTE

A journal of Railway Management, Engineering, Operation, and Railway News. It covers every phase of railway activity. It is truly said of this journal that it is " Read wherever there are Railways." *Weekly* 2s. *Annually* £5 *by post.*

DIESEL RAILWAY TRACTION

A monthly review of world-wide developments in diesel-engine design, practice, and maintenance and diesel railway traction operation. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

SHIPBUILDING AND SHIPPING RECORD

The only publication with direct appeal to both shipowner and shipbuilder. Its world-wide news organisation and technical articles and drawings put it in the forefront of shipping periodicals. *Weekly* 2s. *Annually* £5 *by post.*

COLLIERY ENGINEERING

A practical journal dealing with all aspects of coal production; every branch of coal mining technology is reviewed in detail and special attention is given to mechanisation and labour-saving machinery. *Monthly* 2s. 6d. *Annually* £2 *by post.*

COKE AND GAS

A technical journal dealing with the scientific and technical problems involved in the production of coke and gas in coke ovens and gasworks. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

THE RAILWAY MAGAZINE

A popular magazine containing illustrated articles on Railways and Locomotives. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

NEW COMMONWEALTH

Describes and illustrates significant developments in production, trade, transportation and related spheres in all countries of the Commonwealth. *Monthly* 2s. 6d. *Annually* £2 *by post.*

THE INDUSTRIAL CHEMIST

A technical journal devoted to the progress of applied chemistry and chemical engineering. It is of vital importance to the chemical manufacturer and all who employ chemical processes in their productive operations. *Monthly* 2s. 6d. *Annually* £2 *by post.*

ARCHITECTURE AND BUILDING

A journal for practising and salaried architects, building contractors, designers, and specialists. It deals with the planning, design, construction and the administration of modern building work. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

WOOD

" Wood " is the only magazine of its kind. Primarily concerned with the use of wood, it includes articles on trees and timbers, design and construction in all decorative and practical wood usage, machines and machine practice, and trends in world supply. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

FOOD

A journal devoted to the manufacture, packaging, and marketing of processed foodstuffs. *Monthly* 2s. 6d. *Annually* £2 *by post.*

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development. *Monthly* 2s. 6d. *Annually* £2 *by post.*

MINE AND QUARRY ENGINEERING

Articles of technical nature cover geology, modern methods of prospecting, the winning of ore and stone, the dressing of ore and minerals, and extraction metallurgy. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

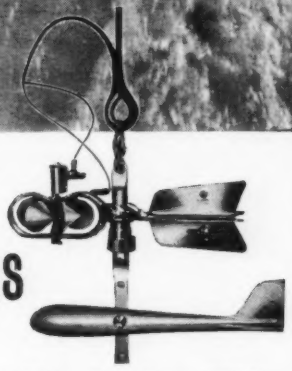
TOTHILL PRESS LIMITED

33, Tothill Street, Westminster, London, S.W.1

For all accurate measurements in

- Catchment Recording and Flood Control
- Irrigation
- Sewerage Schemes
- Hydro-Electric Schemes
- Tidal Current Determinations

Photograph by permission of the New Zealand Ministry of Works

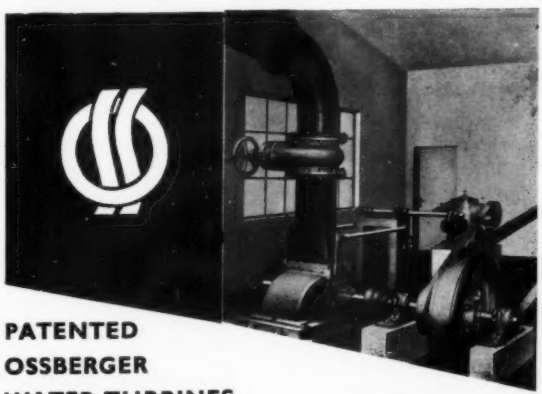


use WATTS WATER CURRENT METERS

Booklet CS 37/c60 gives deta'ls

HILGER & WATTS

HILGER & WATTS LTD · 98 ST PANCRAS WAY · LONDON · NW1 · *Telephone: GULliver 5636*



PATENTED OSSBERGER WATER TURBINES

Specially suitable for economical utilization of fluctuating waters

Range of application
for heads: 1-100 m
Water supply:
10-4000 litres/sec.
Output: up to 300 HP. per unit

Supply of complete small-sized hydro-electric power plants

OSSBERGER-TURBINENFABRIK
WEISENBURG IN BAVARIA · TELEPHONE 2362

Typical Journal Bearing for horizontal Pelton Wheel driven Generator. Shaft diameter 21 inches, R.P.M. 428, Journal load 51 tons.

MICHELL BEARINGS

The original pivoted pad film lubricated bearings. They carry loads with complete reliability and efficiency with downright simplicity for all Hydro-Electrical installations, and for Marine, Mining, Paper-Making Machinery and other requirements.

MICHELL BEARINGS LTD.
SOUTH BENWALL NEWCASTLE UPON TYNE 5
Telephone 34279 Telegrams: MICHBEARO, NEWCASTLE

INDEX TO ADVERTISEMENTS

A

A.C. Plant & Hire Co. Ltd., The ... —
Acciaieria E Tubificio Di Brescia ... —
Allen, W. G. & Sons (Tipton) Ltd. ... —
Allgemeine Elektricitäts-Gesellschaft ... 44
Allis-Chalmers Hydraulic Divson ... 22
Allmanna Svenska Electriska Aktiebolaget ... —
Aluminium Wire & Cable Co. Ltd. ... —
Anderson, Grice, The Company, Ltd. ... —
Ansaldo San Giorgio, S.p.A. ... 36
Ardelt Industries of Canada Ltd. ... —
Armfield Hydraulic Engineering Co. Ltd. ... —
Associated Electrical Industries (Manchester) Ltd. Outside Back Cover
Associated Electrical Industries (Woolwich) Ltd. ... 14
Associated Electrical Industries (Rugby) Ltd. ... 48
Ateliers de Constructions Electriques de Della ... 58
Atlas Copco, A.B. ... 64 & 65

B

Bell, Theodore & Co. Ltd. ... —
Birkett, T. M., Billington & Newton Ltd. ... —
Bochumer Verein ... Inside Back Cover
Bouchayer & Viallet ... —
Boving & Co. Ltd. ... Front Cover
British Insulated Callender's Cables Ltd. ... —
British Pitometer, The Co., Ltd. ... —
British Ropeway Engineering Co. Ltd. ... —
Brown, Boveri & Co. Ltd. ... 23
Bruce, Peebles & Co. Ltd. ... 47
Bucyrus-Erie Co. Ltd. ... 57
Buss, A.G. ... 45
Butters Bros. & Co. Ltd. ... 7

C

Canadian General Electric Co. Ltd. ... —
Canadian Vickers Ltd. ... 10
Canadian Wood Pipe & Tanks Ltd. ... 38
Ceretti & Tanfani Ropeway Co. Ltd. ... 70
Charmilles Engineering Works Ltd. ... 71
Cockburns Ltd. ... 9
Compagnie Industrielle de Travaux ... —
Consolidated Pneumatic Tool Co. Ltd. ... 62
Costruzioni Generali Farsura Cogefar ... —
Craelius Co. Ltd. ... —
Crompton Parkinson (Export) Ltd. ... —

D

De Havilland Propellers Ltd. ... 66
de Roll, Louis, Ironworks Ltd. ... —
Dominion Engineering Co. Ltd. ... 69
Doulton Industrial Porcelains Ltd. ... 54
Drees & Co., G.m.b.H. ... —
Dresser Manufacturing Division ... —

E

Eimco (Gt. Britain) Ltd. ... —
ELIN, A. G. ... —
Elliott Bros. (London) Ltd. ... 41
English Electric Co. Ltd ... 3
English Steel Forge & Engineering Corporation Ltd. —
Escher Wyss Ltd. ... 29

F

Ferranti Ltd. ... 39
Ferrum Montage ... 19
Fischer Ltd., George ... —

G

Galileo Officine di Battaglia Terme ... —
General Electric Co. Ltd. ... —
Gilbert Gilkes & Gordon Ltd. ... 34
Giovanola Freres, S.A. ... 56
Glenfield & Kennedy Ltd. ... 28

H

Harland Engineering Co. Ltd., The ... 60
Hartley's (Stoke-on-Trent) Ltd. ... 70
Henderson, John M. & Co. Ltd. ... 52
Henley's W. T., Telegraph Works Co. Ltd. ... —
Heywood & Co. Ltd. ... —
Hilger & Watts Ltd. ... 73
Hitachi Ltd. ... 15
Holland & Hannen and Cubitts Ltd. ... —
Holman Bros. Ltd. ... 67
Horseley Bridge & Thos. Piggott Ltd. ... —
Huhn, G. ... 72

I

Ingersoll-Rand Co., Inc. ... —
International Engineering Co., Inc. ... —
International General Electric Co. ... 42 & 43

J

Jonneret, S. A. Ateliers de Construction ... —
Joy-Sullivan Ltd. ... —

K

Karlstads Mekaniska Werkstad, Akt. ... 35
Krupp, Fried. Maschinen- und Stahlbau ... —
Kuljian Corporation, The ... 16
Kvaerner Brug ... 33

L

Leffel, James & Company, The ... 49
Lepper Transformatorenwerk August ... —
Le Materiel Electrique, S-W ... —

M

Magrini, S.p.A. ... 53
Mannesmann-Export, G.m.b.H. ... —
Marelli, Ercole & Co., S.p.A. ... —
Maschinenfabrik Augsburg-Nurnberg, A.G. ... 13
Maschinenfabrik Edward Ruch ... 72
Maschinenfabrik B. Maier ... 18
Micanite & Insulators Co. Ltd., The ... —
Michell Bearings Ltd. ... 73
Mitchell Construction Co., The ... 31
Mitsubishi Electric ... 24

N

Newport News Shipbuilding & Dry Dock Co. ... —
Neyrpic ... 50
Nippon Gaishi Kaisha Ltd. ... 51
Nuttall, E., Son & Co. (London) Ltd. ... 32
Nydqvist & Holm, A/B ... —

O

Oerlikon Engineering Company ... —
Ossberger Turbinenfabrik ... 73

P

Phoenix-Rheinrohr, A.G ... —
Pirelli-General Cable Works Ltd. ... 8

R

Ransomes & Rapier Ltd. ... 5
Reyrolle, A. & Co. Ltd. ... Inside Front Cover
Rheinstahl Union Brückenbau-Akt. Ges. ... —
Rip Bits Ltd. ... —
Riva Costruzioni Meccaniche ... —
Rotork Engineering Co. Ltd. ... —
Ruhrstahl, A.G. ... —
Ruston Bucyrus Ltd. ... —

S

S. A. Ateliers De Secheron ... 68
SACE Costruzioni Elettromeccaniche ... —
Sakai Iron Works Co. Ltd. ... 46
Salvi, A. & Co. ... 17
Salzgitter Maschinen Aktiengesellschaft ... 37
Savoisienne ... 59
Scarpa & Magnano ... 6
Siemens-Schuckertwerke, A.G. ... —
Smith, Fredk. & Co. ... —
Smith, S. Morgan Company ... —
Soc. p. Az. Cementi Armati Ing. Mantelli ... 11
Societa Elettro-Morsetterie Volpato ... —
Societa Nazionale Delle Officine Di Savigliano ... 55
Societe Dauphinoise d'Etudes & de Montages ... —
Societe des Forges et Ateliers Du Creusot ... —
Standard Telephones & Cables Ltd. ... —
Steatite & Porcelain Products Ltd. ... 20
Storey, Thos. (Engineers) Ltd. ... —
Strachan & Henshaw Ltd. ... —
Sulzer Bros. (London) Ltd. ... —
Svenska Metallverken, A/B ... 12

T

Tampella OY ... —
Technoexport ... 40
Tees Side Bridge & Engineering Works Ltd. ... —
Tokyo Shibaura Electric Co. Ltd. ... 4
Torno, Giuseppe & Co. ... 25
Tosi, Franco, S.p.A. ... —

V

Vereinigte Osterreichische Eisen- und Stahlwerke 26 & 27
Victor Products Ltd. ... —
Vevey Engineering Works Ltd. ... —
Voith, J. M., G.m.b.H. ... 21

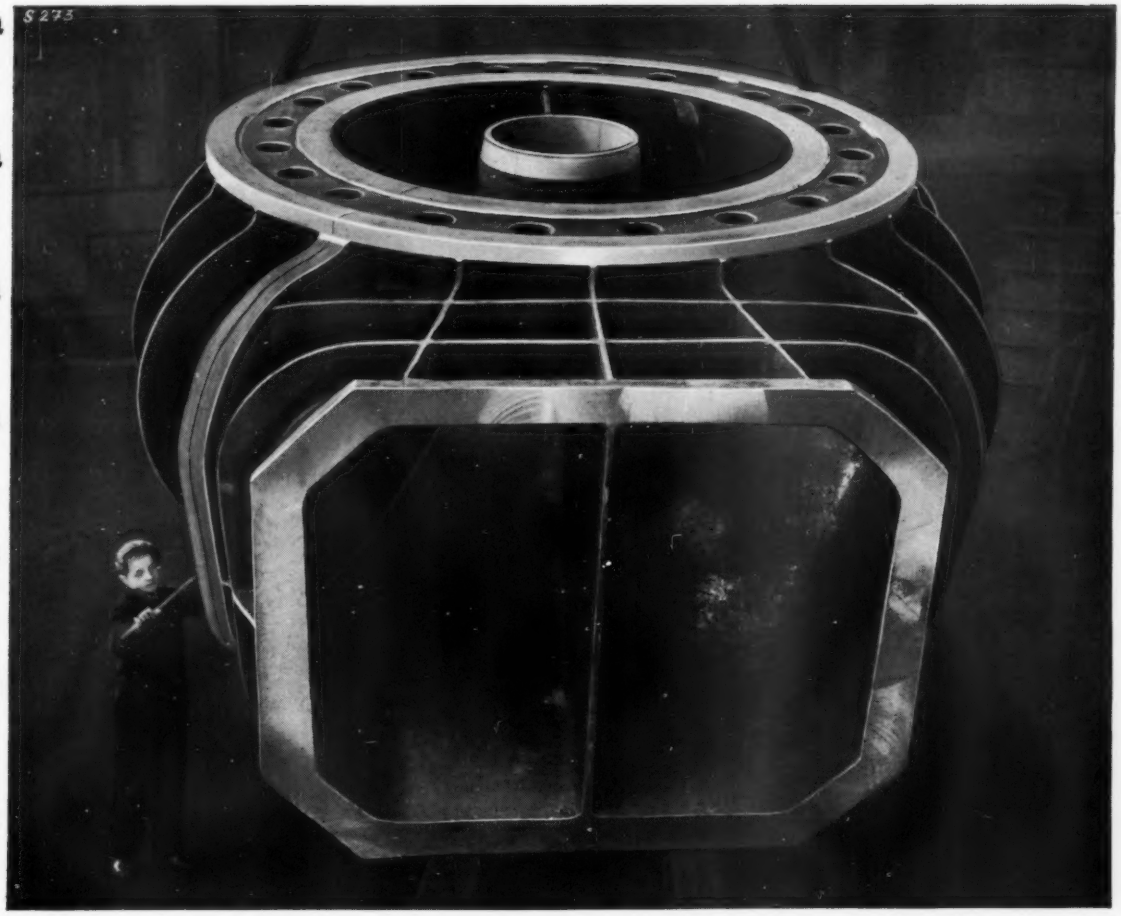
W

Waagner Biro ... —
White, R. & Sons (Engineers) Ltd. ... —
Wood, Hugh & Co. Ltd. ... 30

Y

Yorkshire Electric Transformer Co. Ltd. ... —

LONDON: Published by TOTHILL PRESS LIMITED, Proprietors of WATER POWER, at 33 Tothill Street, Westminster, S.W.1., and Printed by W. & H. SMITH LTD., Evesham, Worcestershire.



May we help you with your **Steel Casting Problems?**

Here is an example from our production:

The above picture shows a suction bend in two parts with reduced wall thickness, for storage pump plant for power station equipped with Francis turbines. — — Weight: 22 tons. Wall thickness: 1 inch. Material: Cast Steel according to BSS 592 Grade A. Max dimensions: 15'3⅛" x 8'4½" x 8'3⅛"

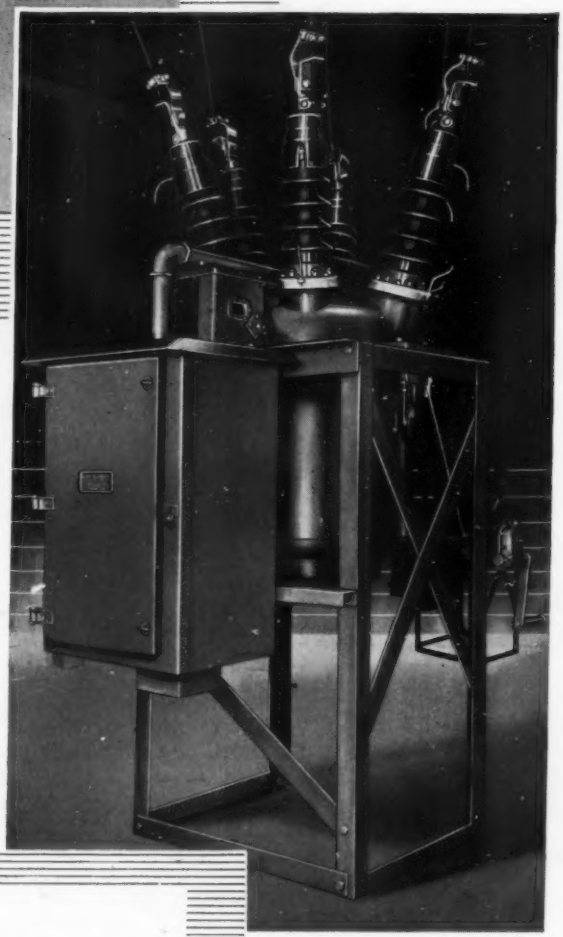
Our production programme for hydro-electric plants includes intricate steel castings for the highest quality and up to the largest dimensions. Very highly stressed castings are made from our BV Vacuum Steel.

Forged steel shafts for pumps and turbines.

B V G Bochumer Verein für Gußstahlfabrikation AG. BOCHUM

Postbox 325, Bochum (Germany) · Telegrams: Gusstahl · Teleprinter: Gusstahl 0825831

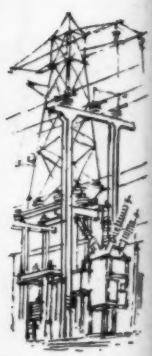
Why TYPE ROP 32 OUTDOOR SWITCHGEAR ?



When a decision must be reached concerning the installation of new, or replacement, OUTDOOR Switchgear the question may well be asked, "Why choose Type ROP.32?" For the very good reason that this class of Switchgear has acquired for itself a high reputation by giving reliable service in many parts of the World, and in varied climatic conditions.

Alternative Operating Mechanisms

The type ROP 32 circuit-breaker can be supplied with (a) Solenoid, (b). Hand wound or motor wound, or (c) Pneumatic closing mechanisms.



FOR 22/33 kV SERVICE

AEI SWITCHGEAR DIVISION

Associated Electrical Industries Limited

Higher Openshaw, Manchester · Trafford Park, Manchester · Willesden, London

F. 774